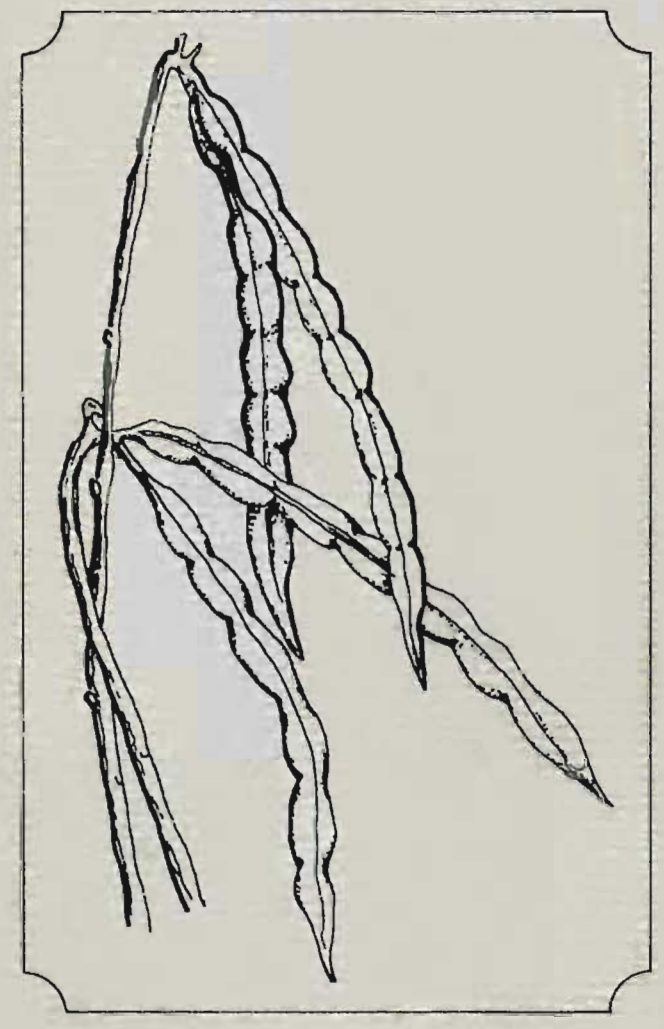
Cowpea Production Training Manual



International Institute of Tropical Agriculture
Manual Series No. 11
1982

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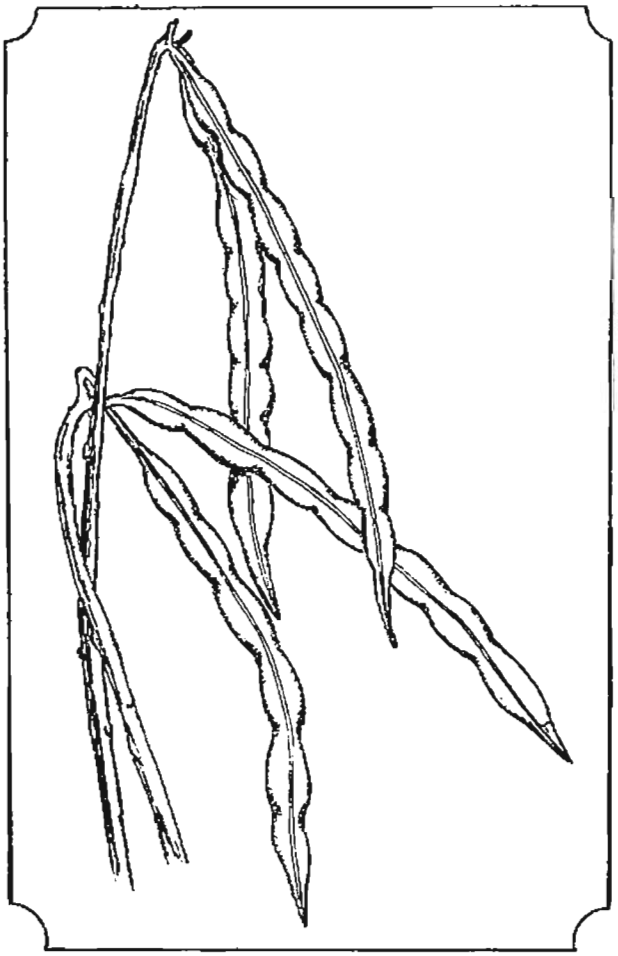

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Foreword

This manual has been compiled to provide information and guidelines relating to all aspects of cowpea production in the humid and sub-humid tropics. It is designed to serve as a basic reference document for participants in IITA's Cowpea Production Training Courses.

Our sincere thanks go to the following scientists who have contributed or revieved the materials that are included in the manual (by alphabetical order).

Dr D.J. Allen, formerly Grain Legume Pathologist, IITA.

Dr B.R. Ntare, Cowpea Breeder, IITA.

Dr B.B. Singh, Cowpea Breeder, IITA.

Dr S.R. Singh, Entomologist and Assistant Director, Grain Legume Improvement Program, IITA.

Dr A.P. Uriyo, Training Officer,(Agronomist) IITA.

Dr R.J. Williams, formerly Grain Legume Pathologist, IITA.

This manual has incorporated earlier monographs produced at IITA on Grain Legume Entomology, by Dr S.R. Singh, and on Grain Legume Pathology, by Drs R.J. Williams and D.J. Allen. Special mention should be made of the efforts of Drs A.P. Uriyo and B.R. Ntare for compiling the rest of the manual and to the secretarial and graphic art staff of the Institute for their contributions.

Mention in the text of trade names of certain products does not constitute approval by IITA to the exclusion of other products that may also be suitable.

It is our sincere hope that this manual will be of assistance to the many research workers and extension supervisors who come to IITA for further training in cowpeas production.

WADE H. REEVES
Assistant Director and Head of Training

18th November, 1982.

CHAPTER ONE

1.1 History and origin of cowpeas.

One of the earliest works concerning the origin of crop species was written by de Candolle and published in 1886. De Candolle listed the disciplines that could assist in the identification of origin as botany, archeology, history and philology. He stressed the importance of the presence of wild forms of the crop plant and forshadowed the concept of centres of diversity as centres of origin that was developed later by Vavilov (1951). Vavilov considered that the area of maximum diversity of a crop plant is also likely to be the centre of domestication of the species. It was anticipated that with most crop plants wild types would be present in the areas where the crop originated and that a high frequency of dominant genes would be found there. Widespread distribution of the wild cowpea is one of the strongest lines of evidence favouring Africa as the origin of the crop. Within Africa, some favoured Ethiopia as the region of origin (Vavilov, 1951), Steel (1972), but others suggested W. Africa (Piper, 1913, Rachie and Roberts, 1974, Rawal, 1975). Thus, cowpeas appear to have originated in West Africa and very likely in Nigeria (Fig. 1.1) where wild and weedy species abound both in the savannah and forest zones (Rawal, 1975).

1.2 Secondary centres of genetic diversity in cowpeas occur elsewhere in Africa, perhaps both in the medium to low elevations, savannah and coastal areas of East Africa and further south. Cowpeas have been cultivated or gathered in tropical Africa since pre-historic times and must have reached Egypt, Arabia and India very early since these were recorded in Sanskritic times. The early Greeks and Romans also knew of cowpeas as they were introduced by the Spaniards into West Indies in the 16th Century reaching the United States about 1706 (Purseglove, 1968).

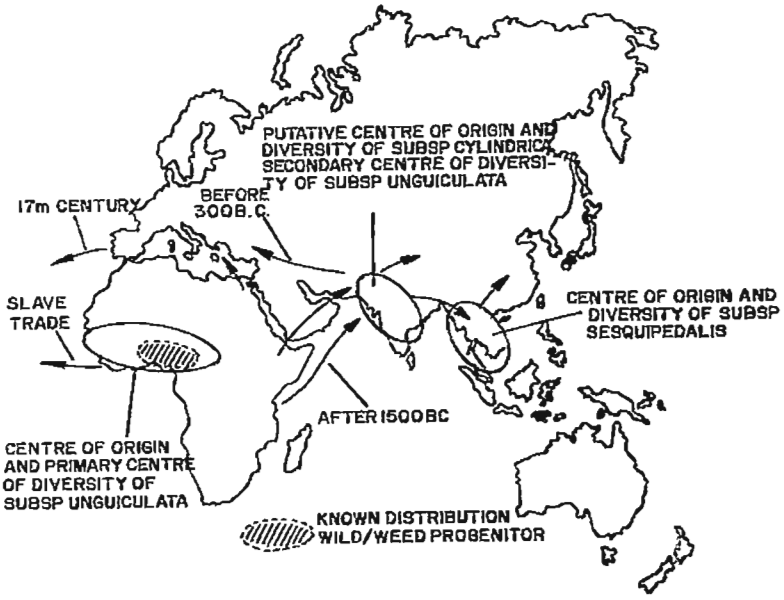

Fig. 1.1: Centres of origin and dispersal routes of cowpeas. (Adapted from Steele, 1980)

1.3 There is evidence that a trade route existed between India and Africa (Sauer, 1952), and i account for the spreading of cowpeas from Africa to Asia. The presence o archeological findings in Africa suggests that their movement is more likely to have been from Africa to India than in the other direction (Flight, 1976).

1.4 The origin of the names given to crops is discussed at length by De Candolle (1959). Where a crop is known by a name derived from the language of another region, it was suggested that the crop may have been introduced from areas where that language is spoken. But de Candolle's concept must be applied cautiously because of the possibilities that migrants may have applied their own names to local crops and that when the commerce of an area is run mainly by one national group, the names used by the group may have become dominant throughout a region. The latter problem is well illustrated in South East Asia where cowpeas are known by a Chinese name e.g. Sitao in the Philippines (Burkill, 1935; Brown, 1954) and Kachang in the Malay peninsula and Indonesia (Burkill, 1935). Confusion may arise because local names often refer to a type of crop e.g. beans, not a species and two examples relevant to cowpeas can be given. The word Katjang, is applied to many species of beans and is reported the origin of the botanical name of pigeon pea, *Cajanus cajan* (De, 1974). The antiquity of cultivation of cowpeas in the Mediterranean area is indicated by the fact that according to Burkill (1935), they were known to the ancient Greeks and Romans as "Phaseolors" or "Phaseolus" although in the past the name was thought to refer to the haricot bean and was borrowed from the genus *phaseolus*. Some of the names given to cowpeas are listed below (Adapted from Lush, 1978).

Subspecies	Synonym
Unguiculata	*Vigna sinensis*, black eye or pea, cowpea southern bean, Kaffir pea, serido bean, farin wake, niebe, lubia.
Cylindrica	*V. catjang*, *V. cylindrica*, *V. sinensis catjang* cowpea, lubia, pusa phalguni, barbati, charti, catjang tauge (bean sprout).
Sesiquepedalis	*V. sesiquepedalis*, *V. sinensis*, yard-long bean, asparagus bean, bodi bean, snake bean, sitao, katchang panjang (long-bean). Kachang belut, kachang perut, ayam (fowl's gut bean) pusa borsati.
Mensensis	*V. unguiculata* "wild" cowpea.
Dekindtiana	*V. unguiculata* "wild" cowpea, waken bei bei (forbidden bean), waken daji (bush bean) waken gizo (spider bean).

1.5 Much of the confusion surrounding the origin of cowpeas results from the predominance of different cultivated types in different regions, subspecies *unguiculata* in Africa, *cylindrica* in Asia and *sesquipedalis* in South East Asia but all three subspecies can be found in each region. De Candolle noted that the abundance of a species is not a proof of its antiquity, a point that can be will illustrated by the widespread cultivation of wheat and soybean in North America. Over all, the evidence favours Africa as the origin of cowpea, but this does not exclude the possibility that the subspecies *cylindrica* and *sesquipedalis* were developed by selection in Asia after introduction from

Africa as suggested by Westphal (1974).

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CHAPTER TWO

2.1 Importance of cowpea and its distribution.

Cowpea is the most important pulse in tropical Africa, and it is grown from along the southern fringes of the Sahara from the west coast to East Africa and southwards. Exact figures on area cultivated for cowpeas in Africa are not available because of lack of reliable statistical enumeration. This is partly bbeeaaaaecowpea is often cultivated in mixtures with other crops and it is mostly used for home consumption. Also the portion marketed is often not done through official channels where trade statistics can be maintained. Similarly unreported kitchen garden, vegetable use and inaccurate reporting as "dry beans" may under-estimate real production by as much as 50% or more suggesting the equivalent of more than 2 million metric tons annually (Rachie and Rawal, 1976).

Production trends for some countries for the period 1965-1980 are shown in Table 2.1. Africa produces over 75% of the crop, principally in Nigeria, Upper Volta, Uganda, Niger and Senegal (Rachie and Rawal, 1976). Seed yields are very low often ranging from 0.15 - 0.2 t/ha (Rachie *et al.*, 1975), but under favourable conditions, productivity levels of 1500 to 2000 kg/ha are realized within 60 to 70 days from planting (Rachie, 1972). On the basis of available data,sustained increased production over the last 10 years was recorded from Malawi, Niger, Nigeria, Upper Volta and Zimbabwe. In Tanzania, production declined in the early 1970's but in the late 1970's it showed considerable improvement in production. In Uganda total production deteriorated sharply after 1975. Production also declined in Madagascar and Senegal during the 1970's.

Table 2.1: Cowpea production in Africa, 1965-1980*

Metric tons/year '000

Country	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Madagascar	3.2	3.5	3.6	3.4	3.8	3.7	3.5	3.4	1.9	2.0	2.5	1.5	1.9	2.1	2.2	2.5
Malawi	27.0	30.0	31.0	32.0	33	34	35	36	37	28	39	40	41	41	40	44
Niger	56.0	67.6	77	74.2	83.3	84.3	72.1	144.1	92.2	132.7	218.5	216	206.8	277.9	250	25
Nigeria	560.0	580.0	550	648	931	1008	462	560	550	650	850	980	750	800	830	850
Senegal	14.6	18.2	30.5	17.1	22.6	17.8	25.9	10.81	16.24	32.5	20.8	16.36	11.73	13.0	13	13
Tanzania	14.3	12.82	8.35	12.27	17.99	12.02	8.56	10.26	10.0	11.0	13	13	25	20	20	22
Uganda	26.8	23.4	61	64	55.6	56	58	61.9	50.3	63.9	56.9	34.8	34.6	39.7	44.7	49.7
Upper Volta	70.2	58.0	60	66	75	75	80	75	80	85	90	90	90	95	95	95
Zimbabwe	0.31	0.22	0.3	0.25	0.3	0.32	0.32	0.34	0.34	0.35	0.36	0.36	0.36	0.36	0.36	0.38

* Source: Various sources such as Annual Reports of Ministeries of Agriculture.

Several production constraints to cowpeas exist in tropical Africa.

(i) Climate - is often characterized by insufficient, poorly distributed, or excessive moisture, lack of sufficient insolation; and extremes of temperature.

(ii) Soils - are usually poor in physical structure; low water holding capacity; have a deficiency of organic matter and extremes of low or unbalanced fertility; and often unfavourable microbiological conditions.

(iii) Insect pests - Several insect pests especially thrips, pod sucking pests such as *Maruca* and storage pest bruchids are a serious constraint to cowpea production.

In the absence of diseases, crop loss varies from complete loss to over 50%, without insecticide as shown in Table 2.2

Table 2.2: Cowpea yield losses in Africa due to pests.

Region		% Yield loss	Period	Reference
W. Africa:	Northern Nigeria	78	1961-1962	Booker, 1965
	Southern Nigeria	80	1966-1967	Taylor, 1968
E. Africa:	Tanzania	74	1972-1974	Kayumbo, 1978
	Uganda	75	1970-1971	Koeler and Metha, 1972.

(iv) Diseases - Depending on conditions for disease spread and stage of crop growth, susceptible varieties can show 50-100% loss from cowpea golden mosaic virus, and cowpea yellow mosaic virus, in the humid zone, and in the savannah zone with cowpea aphid-born virus,

scab and colletotrichum pod blotch. Severe damage with up to 50% yield loss can also occur from blight and bacterial blight.

(v) Low yield potential of majority of farmer's land races. Local cowpeas have been selected for survival as a minor crop under minimal inputs, and usually as the last sown component of a relay cropping system with little nutrient or moisture reserves to draw upon. Sowing densities are usually low, and the philosophy is that a failure is a small loss to sustain but if there is some produce (although small), this will mainly be profit. In the savannah zone 10-12°N the local cowpeas tend not to flower until the days become shorter in October/November, and so have been selected to mature on residual moisture after the end of rainy season.

(vi) Storage loss - Post harvest losses of cowpea in storage are mainly due to the storage weevil, *Callosobruchus maculatus*. The initial infestation begins in the field, and in shelled seed the pest multiplies rapidly in storage with a generation time of 3-4 weeks. Thus losses tend to be greater in the marketing sector where mostly shelled grain is sold, and losses are less severe where farmers tend to store seed in the pod. Air tight storage, and fumigant chemicals can provide control, but these are difficult to achieve in practice.

(vii) Subsistance cropping and marketable surpluses. With the very low on-farm yield levels in West Africa, most production is consumed by the farmer and his family. Only a small proportion of the crop is marketed. Cowpeas could be a very useful and popular addition to urban and village diets, and one of high protein value.

Increased production will be best achieved by increased production per unit area, than by increased area sown. For increased production per area, management practices are needed such as increased seeding rate, better weed control, and chemical protection against pests. But these inputs are an extra cost and the farmer should use improved varieties which are yield responsive to improved management. This increased output per hectare should be accompanied by the development of viable and sustained marketing facilities to ensure that the farmer obtains a good return on his investment. Partial genetic resistance to pests, high levels of disease resistance, adaptation to local conditions, and acceptable seed qualities, are all objectives of the IITA cowpea breeding program. New lines from this program have been selected to reduce risk to the farmer and to show higher returns to improved management than local cultivars. If the lines are not immediately acceptable, either they can be re-selected in some cases such as for a particular seed colour, or they can be valuable parents for crossing with local types in a national breeding program.

2.2. Uses of cowpeas. Cowpeas are extensively grown in Africa and are used for several purposes.

2.2.1 Harvesting the leaves.

The young shoots, leaves, and even roots of cowpeas are used as pot herbs in most parts of Africa (Rachie and Roberts, 1974). If the tender green leaves are plucked before the reproduction phase begins, the plant continues to

produce new leaves. Mehta (1971) demonstrated that it was possible to remove all tender leaves up to a maximum of three times at weekly intervals during the vegetative stage of growth without reducing the final seed yield.

2.2.2 Utilization.

The primary use of cowpeas is for the dry pulse; green pods, green seeds, seedlings, and tender young leaves are often used as pot herbs. Canning and freezing shelled green peas has become an important industry in the United States. The vegetation also makes excellent hay, and the surplus culled and broken seeds can be used as a protein concentrate for domestic animals. In Africa, cowpeas are frequently soaked, the testas are removed by rubbing, and they are then ground in order to make dough. To facilitate this process, large cowpeas with rough or wrinkled testas are preferred. In other tropical regions, and to some extent also in Africa,cowpeas are cooked directly as vegetables, Where this is the practice the preference goes toward cowpeas with smooth seed. Cowpeas require less cooking time than most other legumes, an important advantage in areas where firewood is in short supply.

2.2.3 Food preparation.

In Africa, cowpeas are consumed in three basic forms with many minor variations. Most frequently they are cooked together with vegetables, spices, and other ingredients to make a thick soup or gruel, which is eaten in association with the basic staple such as preparations of cassava, yams, plantain, or cereals. The second method of preparation is a deep-fried cake (akara balls), prepared from a dough of flour made from ground-up shelled cowpeas to which onions and seasoning are added. Cowpeas are also eaten as steamed bean

cakes (moin-moin in Nigeria), prepared from cowpea flour to which chopped onions and seasonings have been added. In preparing the flour the testas are removed by soaking the dry seeds in water for a short period and rubbing. Rough or wrinkled testas are preferred as they soak quickly and are more easily removed.

2.4 Nutritive qualities.

In terms of proximate principles, the dry cowpeas pulse contains the following constituents (Rachie and Roberts, 1974).

Constituent	Percent
Water	11.0
Protein	23.4
Carbohydrate	56.8
Fat	1.3
Fibre	3.9
Ash	3.6

Contents of calcium (90 mg. per 100g), iron (6-7mg per 100g), nicotinic acid (2mg per 100g), and thiamin (0.9mg per 100g) are high and contribute substantially to these requirements in tropical diets (Platt, 1962).

Crude protein levels are highly variabal, ranging from 19 percent to 35 percent on a dry-weight basis, depending on genotype, seed yield, management, and environment. The amino acid spectrum is excellent except that methionine and cystine tend to be sub-optimum for monogastric nutrition, as in most other grain-legume species. A range of essential amino-acid content is reported by several investigators as follows (Rachie and Silvestre, 1977).

Amino Acid	Percentage total protein	Average percentage total protein
Lysine	5.7-9.6	6.6
Cystine	0.7-1.7	0.9
Methionine	0.7-1.6	0.9
Histidine	2.7-4.0	3.3
Threonine	3.4-5.3	4.1
Tryptophane	0.6-1.6	0.9

According to Liener (1969) levels of toxic substances and antimetabolites like the trypsin inhibitor, haemaglutinnins, and flatus factors are minimal in cowpeas. Nevertheless, cowpeas have been shown to contain trypsin and chymotrypsin inhibitors (Ventura and Filho, 1967) and may have a cyanogen, with a titre as high as 2mg per 100ml extract (Montgomery, 1964). Therefore, cooking is needed to inactivate these undesirable principles.

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CHAPTER THREE

BOTANY AND PHYSIOLOGY OF COWPEAS

3.1 Taxonomy.

Vigna is a parantropica genus of about 170 species with the largest number endemic in Africa; but several in India, Australia and the New World. Vercourt (1970) recognised five subspecies of *V. unguiculata* of which the subspecies *sesquipedalis*, *unguiculata* and *cylindrica* are cultivated, whereas *dekindtiana* and *mensensis* are spontaneous. Studies at IITA have indicated that hybrids among these subspecies occur in nature and are easy to make. Artificial hybrids were fertile and genetic analyses showed simple inheritance for the commonly used taxonomic characters that distinguish them. Continuous variation with an almost complete series of intergrades exists among the cultivated taxa.

The methods of formal taxonomy have not been satisfactory for the classification of cultivated plants. Harlan and de Wet (1971) proposed a system of classification based on the structure of a gene pool characterized by assigning taxa to primary, secondary and tertiary gene pools. According to this system and supported by evidence from studies at IITA, the primary gene pool of *V. unguiculata* comprises all the cultivated forms as subspecies *unguiculata* with three races based on the conventionally used taxonomic characters. The spontaneous group includes the subspecies *dekindtiana*, *mensensis* and the hairy variant *pubescens* that was previously designated as *V. pubescens*.

Extensive crossability studies under green-house condition at IITA indicated that *V. unguiculata* does not have the secondary gene pool as defined by Harlan and de Wet (1971). The number of the tertiary gene pools are not as yet fully explored; so like many other legumes, *V. unguiculata* may not have secondary and tertiary gene pools.

3.2 Reproduction.

Cowpea and its closely related subspecies are deploid (2n=22) and inter-fertile (Faris, 1964). The subspecies *mensensis*, however, was probably not represented in Fari's collection and evidence suggests that it is not fully fertile with the other subspecies (Lush, 1979). Crosses between subsp. *mensensis* and domesticated fail when subsp. *mensensis* is the female parent, and when it is male they result in shrivelled seeds and seedlings of low vigour (Rawal *et al.*, 1975). If subsp. *mensensis* is the female parent in crosses with *dekindtiana*, seeds are produced (Lush, 1979) but they are shrivelled and weigh only 12mg each compared to 21 and 26mg in the female and male parents, respectively.

Cowpea is predominantly a self-pollinated crop although some degree of outcrossing depending on the activity of pollinating insects has been reported (Rachie and Roberts, 1974). Cowpeas make a good material for genetic studies. The flowers are large and easily emasculated. Artificial crosses can be made easily and seed set and Viability of the hybrid seed are usually good (Ojomo, 1970). However, attempts to cross *V. unguiculata* with other species of *Vigna* so far have been unsuccessful (Sene and Bhowal 1960, Faris (1965).

A recessive gene for male sterility (ms ms) has been reported in cowpea (Sen and Bhowal, 1961, Rachie *et al.*, 1974), and is likely that insects occassionally emasculate unpollinated flowers. Bees have been reported as major insect pollinators and are usually found in large numbers in cowpea fields (Lelejı, 1973). A constricted petal form of male sterility in which the pistil protrudes above anthers has also been found in cowpeas. Both of these systems ensure cross pollination in the cowpea in the presence of a large number of pollinators like bees.

3.3 Morphology.

Morphological variability in the cultivated forms of *V. unguiculata* is enormous (Porter *et al.*, 1975). Growth habit ranges from erect, determinate non-branching types to prostrate or climbing, indeterminate, profusely branching forms. Under short day photoperiod (11 hours 30 minutes) during the second season (August-October) at Ibadan (7° 30' N), flowering takes place from 33 to 90 days after planting. However, the pod filling period is relatively short, ranging from 17 to 24 days after fertilization.

Cultivated cowpeas are usually glabrous, annual herbs with a strong, deep tap root and many branches form from it in the surface of the soil. The root nodules are smooth and spherical, about 5mm in diameter, they are numerous on the tap root and its main branches, but sparse on the smaller roots.

Stems are cylindrical but slightly ribbed, twisting, sometimes hollow and glabrous with scattered minute spinelets. Pigmentation on the stem varies from none or localized purple pigment at nodes to solid purple.

Each node subtends two ovate, cordate or lanceolate, appendaged, accominate stipules with parallel convergent veins. The axillary bud may develop into a branch or flower-bearing peduncle. Leaves are alternate trifoliate with one symmetrical terminal leaflet ranging from circular to hastate in shape and two asymmetrical leaflets. Petioles vary from 3 to 25cm with swollen pulvinus at the base of the petioles. Stipellae are one per each lateral leaflet and two for the terminal leaflet.

The inflorescence is an unbranched axillary receme bearing several flowers at the terminal end of peduncles. The peduncles vary from 5 to 60cm in length and are slightly twisted and ribbed. The rachis is contracted with paired fertile flowers and abortive flowers that exude a sweet liquid when shed (Ojehomon, 1968). Bracts are one per flower and deciduous at early stages of floral development. Pedicels are very short with two deciduous bracteoles.

The calyx is longitudinally ribbed, tabular with 2 to 15mm long sub equal lobes that are sometimes purple. The corolla is papilliona-ceous with an erect standard petal spreading at the time of flower opening. The pigmentation pattern of the corolla varies from white to solid mauve with yellow spots near the base of the standard petal. The wings are adherent to the boat shaped keel enclosing the androecium and gynoecium.

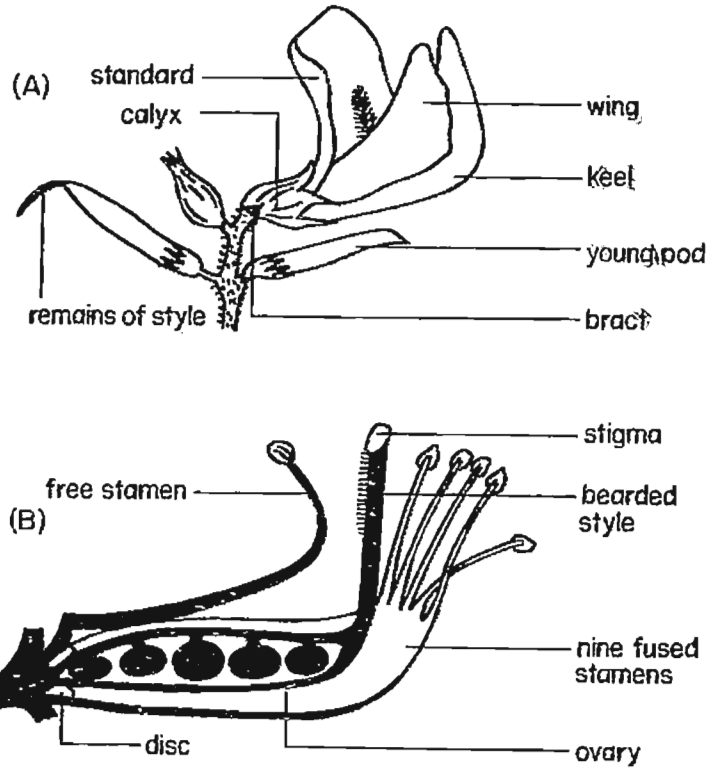

Fig. 3.1: Vigna unguiculata: Cowpea (A) A flower and young pods (x1½). (B) A diagram to illustrate the essential organs of the flower.

The stamens are diadelphous (9+1) with the vexillary stamen free and nine fused forming a tubular sheath around gynoecium (Fig. 3.1). The length of the pods may vary from less than 11cm to more than 100cm with many locules per pod.

The pigmentation pattern of the pod varies from green to green with a purple tip and/or suture and valves, to purple or brown at the immature stage; and straw to straw with dull black splashes to deep purple or brown at maturity.

Seed sizes vary and may be from square to kidney-shaped and frequently laterally compressed. Genetic studies by Franckowiak (1975) and Franckowiak and Baker (1975) revealed a wide range of seed coat colours and eye pattern. Details of these are also described by Porter *et al.*, (1975). The eye of the cowpea refers to the pigmented area around the hilum. The different shapes of this pigmented area form the basis for the classification of the eye in the various patterns. Only after determining the pattern of the eye is the colour of the eye evaluated. Indeed pod, and seed size are the chief diagnostic characters of the three cultivated subspecies as follows:

Subsp. *Unguiculata*: Pods 10-30cm long, pendent. Seeds 5-12mm long, very rarely shorter than 6mm.

Subsp. *cylindrica*: Pods 7.5 - 13cm long, usually erect, seeds 5-6mm long.

Subsp. *sesquipedalis*: Pods longer than 30cm, flabby, seeds usually 8-12mm long.

The two wild subsepcies have scabrous, dehiscent pods and small dark speckled seeds. Germination is epigeal.

3.4 Eye patterns:

In the following descriptions the "back" of the hilum refers to the micropylar end. The "body" of the seed is non-eye portion.

Self - coloured group: The eye covers the entire seed.

Watson group: The eye encircles the back of the hilum in a narrow ring, widens at the side of the hilum and spills over the non-micropylar portion of the seed with an indistinct margin. The extra width at the sides of the hilum distinguishes the group from the N group.

Holstein group: The eye encircles the back of the hilum in a narrow ring, widens at the sides, and then extends out in front of the hilum to varying degrees. Here the entire margin of the eye is characteristically distinct.

Small eye group: The eye in this group has a distinct margin, but is smaller than holstein eye.

Narrow eye: (Hilum ring): The eye fills the narrow grove around the hilum and spills out of the grove in front of the hilum for a short distant; presenting an indistinct margin in front.

Kabba group: The eye fills the narrow grove all round the hilum and the body is speckled. A blue halo is also found around the hilum.

Eye absent or very small: In this group, the W group for eye colour is always used.

3.5 Eye colours.

a) Black and blue

b) Speckling: an evenly distributed line trippling.

c) Tan and brown

d) Red

e) Mottled: Typical of this group is absence of dark brown pigment around the hilum.

f) Victor: Combination of mottling with speckling

g) Black spots or blue on mottling.

h) White, cream, brown splash or grey; This group is used only with the small eye or eye absent pattern group.

Testa texture varies from smooth to rough, wrinkled, loose and split. The 100 seed weight ranges from less than 2 to 33gm.

3.6 Physiology of cowpeas.

In West Africa both the total amount of rain and the duration of the wet season decrease from south to north, and the isopleths of these variates run approximatley east and west with the lines of latitude. Local populations of cowpeas grown by farmers in West Africa are planted at times that are dictated largely by the onset of rains; and they generally start later and end earlier as one moves northward, the onset of flowering of local varieties of cowpea has been ascribed to photoperiod control, although details of this mechanism for varieties at different latitudes have not been elucidated (Wein and Summerfield, 1980).

3.6.1 Light and photoperiod.

Cultivars of the cowpea adapted in the higher tropical latitudes have a short-day type of photoperiodic response. This serves to regulate flowering in such a way that pods are formed and mature towards the end of the rainy season. Short-day types often produce excessive vegetation in relation to grain yield when planted earlier than is optimal for that particular cultivar (Summerfield *et al.*, 1975). Photo-insensitive (day-neutral) cultivars can be

grown in both low tropical latitudes and in temperate regions as summer crops (Rachie and Silvestre, 1977).

Recently, Summerfield and Wien (1980) studied the adaptation to photoperiod of traditional cultivars, where 24 accessions collected from farmers' fields in Nigeria and Niger were sown at four sites ranging in latitude from 7.5°N to 13.5°N on several dates during the 1977 growing season. From flowering data taken at 2-3 day intervals, and from morphological observations made at 45 and 79 days after planting, the lines were classified into four categories of increasing sensitivity to photoperiod. Those that originated from 9-11°N were most sensitive. They did not initiate reproductive primodia unless the days were shorter than 12 hours 46 minutes. In general, lines from more northerly locations were less sensitive to daylength, although the range of responses in lines from a particular latitude was considerable. The initiation of reproductive primodia and the expansion of flowers from visible buds required two distinct photoperiod "triggers" - longer and shorter, respectively. This allows the plant to accumulate reproductive primodia which flower more or less simultaneously when the natural daylength becomes sufficiently short.

3.6.2 The effect of temperature on the growth of cowpeas.

Summerfield and Huxley (1973) demonstrated the profound effects of night temperatures on both vegetative and reproductive development in terms of growth, days to first flower, and seed yield in 30 cultivars which they studied. Dirunal temperature change influences *Rhizobium* activity and nodulation as shown by Dart and Mercer (1965). Maximum dry-matter production

occurred with the combination of 27°C day and 22°C night temperatures when combinations of 21-36°C day temperatures with 16-31°C night temperatures were imposed Dart and Mercer (1965) concluded that air temperature is of considerably greater importance than either light intensity or nitrogenous fertilizers in determining the efficient functioning of the symbiotic system.

In order to determine whether the responses to night and day temperatures of local populations of cowpeas varied in any systematic fashion, Wien and Summerfield (1980), screened them at 19°C and 24°C night temperature and at 27°C and 33°C day temperature in glasshouses. Although in many of the lines flowering was delayed by the cooler night temperature, this factor does not vary sufficiently during the growing season in most cowpea growing regions of West Africa to affect the time of flowering in the field significantly. Day temperature, however, increased by 3-4 at the end of the rainy season, particularly in the northern most locations. Warm days decreased yield less in northern accessions than in southern ones, indicating that the former are to some extent adapted to the temperature regimes they are likely to experience in the field.

3.6.3 Water requirements of the cowpea.

Cowpeas are highly drought resistant, but may also be reasonably tolerant of high soil moisture (IITA, 1973). Most cowpeas are grown under rain-fed conditions, but they may also be grown with surface or sprinkler irrigation. Cowpeas may be cultivated without rainfall by growing them after swamp rice on the residual moisture of high water-holding capacity.

Excess, as well as deficient, water can limit cowpea growth and yield.

For example, short periods of water logging restricted nitrogen fixation, vegetative growth, and seed production in cowpeas that were grown in pots in simulated tropical environments (Minchin and Summerfield, 1976). In actual practice, the real life in many tropical environments is a mixture of drought and heavy rain (Elston and Bunting, 1980).

According to Summerfield and Huxley (1973) moisture stress can reduce productivity during the period from emergence to first flower, but with determinate cultivars, may not significantly affect yields when water stress occurs thereafter. Doku (1970) found nodulation to be reduced by water stress, particularly when combined with experimentally lenghtened days (to 16 hours).

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CHAPTER FOUR

LAND PREPARATION AND PLANTING

4.1. Land preparation.

In the traditional methods of farming based on bush fallow and related systems of replenishing soil fertility, a wide range of land preparation systems are used in different agro-ecological regions of tropical Africa. After slashing the weeds and bush regrowth farmers commonly use fire to dispose of the excess vegetation and perhaps to supply some meager nutrient elements.

In many regions of West Africa, particularly in the region of Alfisols with gravel layers at shallow depth, farmers plant on small hillocks. These mounds are prepared by heaping the surface layer to increase the effective soil depth (Lal, 1979).

Hand hoeing is the most widely used cultivation method in much of tropical Africa. In areas where livestock are kept, bullock-driven implements are commonly used for mechanical seedbed preparation.

Increasingly tractor mounted implements are being used for seedbed preparation in much of tropical Africa. Variations to conventional tillage such as reduced tillage which refers to the methods of seedbed preparation whereby the frequency of the use of various conventional tillage equipment is minimized are on the increase. In some parts of Africa zero tillage is gaining ground.

Tropical soils generally have a thin surface horizon, low water holding capacity and poor root penetrability (Nangju, 1979). In West Africa, where the soils are extremely sandy and susceptible to water erosion, the introduction of ploughing and harrowing often leads to loss of top soil and a dramatic increase in crop yield after several years.

Zero tillage or minimum tillage is synonymous with conservation tillage and implies maximum retention of crop residue on the soil surface. Minimum tillage is gaining popularity in some parts of Africa as a way of conserving the soil.

4.2 Date of planting:

It is important to choose an appropriate planting date for cowpeas in order to obtain high yield and high seed quality. There are several factors which must be considered in choosing a suitable planting date for cowpeas. The ideal planting date for cowpeas would assure that:

(i) Soil conditions are favourable for seedling emergence;

(ii) Growing cowpeas are subjected to shortening days;

(iii) Growing season is sufficiently longer to enable pods to develop fully;

(iv) Pods ripen at the end of rainy season, and

(v) Insect and disease incidence is low during crop growth.

Day-neutral cowpeas can be planted anytime of the year in low tropical latitudes, when moisture and fertility are adequate and if satisfactory pest control can be practised (IITA, 1973). However, it is highly desirable for planting time to be restricted so that maturation occurs during bright, sunny dry weather. This helps to reduce pod and seed damage from both insects and diseases (MacDonald, 1970). Most cultivars begin to flower 35-70 days from germination. The date of planting should be so timed that protracted rainy periods are over by the time the crop begins flowering.

As an illustration we can take an example of rainfall patterns at Ibadan, Samaru and Port-Harcourt in Nigeria. Ibadan has bimodal rainfall, and short daylength occurs between July and December. Under these conditions cowpea is best planted as soon as the second rainy season begins (late August or early September). Cowpea will be harvested in November or December which is the dry season under Ibadan conditions. Day-length sensitive cultivars are not well adapted to growing in the first season in bimodal rainfall regions. In Samaru the rainfall pattern is monomodal, hence crops are grown only once a year. Generally in this area millets or sorghums are planted as soon as the first rains come in May. Cowpeas are planted later around June or July often in association with the cereals. By the time the cowpeas are ripe it will be well into the dry season. In Port Harcourt total rainfall per year is almost twice that in Ibadan. Rain begins in February and continues until December. Under this condition it is very difficult to decide when one should grow short maturing grain legumes such as cowpeas and soybeans. To plant these legumes 2 to 3 months before the last rain means that planting has to be done during the peak of the rainy season in August to September. At this time water logging and diseases are serious problems. For humid regions such as Port-Harcourt it is probably better to grow vegetable legumes than pulses. These include climbing cowpea (*Vigna sesquipedalis*) and winged bean which are harvested as young leaves and green immature pods, and are well adapted to acid soils as in the case of Port Harcourt soil. These legumes can be planted as soon as the rain comes and harvesting can be done during the rainy season without affecting yield, and provided green pods are harvested as soon as they reach the right size, and insect pests can be adequately controlled.

4.3 Planting method:

After the land has been prepared and the planting date chosen, then the seeds need to be prepared. Seed preparation before planting includes:

(i) Seed cleaning - Bad and damaged seeds have to be removed so that the planting materials will consist of only good, clean seeds which can produce healthy and vigorous seedlings.

(ii) Germination test - If the viability of the seed is in doubt, a germination test should be conducted before planting. This is especially recommended with old seeds, and sometimes even with new seeds if not dried and stored properly. Knowing the percent of germination of the seed to be used, seeding rate can be adjusted to obtain an optimum stand in the field.

(iii) Seed dressing - Seed needs to be treated with fungicides such as chloroneb (Demosan), thiram (Arasan) and Aldrex-T at the rate of 2-4g material per kg seed. These fungicides are effective for control of seedling diseases and for obtaining a good stand.

(iv) Ensuring good nodulation - Inoculation of cowpea is seldom necessary in the major growing areas as there is usually an abundance of indigenous strains capable of good nodulation (Sellschop, 1962).

Very little response to nitrogenous fertilizers is observed when plants are properly nodulated. Therefore, it is necessary to improve conditions tending to maximize the rhizobial process than to use nitrogenous fertilizers. Ways of ensuring this include the following:

(a) Improve soil moisture and mulching and avoid excessive cultivation (Masefield, 1957).

(b) Plant when the soil temperatures are in the range of 20-30°C. This is optimum for primary root nodulation according to Dart and Mercer (1965). The number of plants nodulating as well as numbers of nodules produced decrease linearly as temperatures increase from 31 to 42°C (Philpotts, 1967).

(c) For optimum nodulation and subsequent growth and development, the photoperiods should not be longer than 16 hours (Doku, 1970).

(d) Apply sufficient phosphate and potash at the time of seedbed preparation to increase nodulation (Tewari, 1965).

(e) Avoid high soil nitrogen levels, which inhibit nodulation during early growth (Ezedinma, 1964).

Fixation of nitrogen by a well nodulated cowpea crop was estimated by Nutman (1971) to range from 73-240kg/ha. Nitrogenous substances accumulate in leaves during vegetative growth and they are then transported to the seed during grain filling. Each tonne of cowpeas harvested is estimated to remove about 40kg of nitrogen (Jacquinot, 1967). If Nutman's and Jacqunot's estimates are correct, it follows that if conditions for nodulation are favourable,nitrogen fixation provides adequate nitrogen to sustain cowpea production.

Nitrogen is the most expensive fertilizer and its use is imperative on soils under continuous cultivation. But inclusion of legumes in rotation minimizes the need for nitrogen fertilization for the succeeding cereal crops and it also improves the soil condition.

4.4 Populations and spatial arrangements.

Method of planting will depend on the plant spacing to be used, and the degree of care that the plants will receive after planting. Some of the planting methods commonly used are:

(i) Broadcast method - where seeds are broadcast on the surface, and either left there or incorporated into the soil. This method is not recommended since percent of emergence is generally low, spacing is random and seedlings are poorly distributed on soil.

(ii) Hill planting - common in traditional agriculture.

(iii) Row planting - common when using mechanization and it is recommended for manual planting also.

The spacing of plants within rows is determined by the type of variety being planted:

Cowpeas are usually planted in rows 75-100cm apart, 15-25cm apart within the row, and a seed rate of 17-28kg/ha (Rachie and Silvestre, 1977). In African mixed cropping systems cowpea seeds are frequently planted at a rate of 22-33kg/ha (Rachie and Silvestre, 1977). In Francophone Africa, hill plantings (2-3 seeds per drop) are recommended at spacing of 50x50cm or 50x 60cm for early cultivars, and wider for late or spreading cultivars (Silvestre, 1970). The spacing listed in Table 4.1 are common plant spacings for cowpea monocrop grown around Ibadan.

Table 4.1: Common plant spacings for cowpea grown in monocrop at Ibadan.

Variety and growth condition	Spacing (cm)	Plant population Plants/ha
Erect variety, good growth condition	20 x 75	67,000
Erect variety, poor " "	20 x 50	100,000
Semierect variety, good growth "	20 x 75	67,000
	20 x 100	50,000
Spreading variety, photoperiod non-sensitive		50,000
	20 x 100	30,000
Spreading variety, photoperiod sensitive	20 x 100	50,000

The spacings listed are not absolute but are valid over fairly wide ranges. Some varieties, such as VITA-1 and VITA-3, show decreases in yield as plant population increased because they develop excessive vegetative growth and have fewer flowers.

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CHAPTER FIVE

GRAIN LEGUMES IN CROPPING SYSTEMS IN THE TROPICS

5.1 Introduction

The most important grain legume in Africa is cowpea. About 98% of cowpeas grown in Africa are intercropped (Arnon, 1972). Intercropping is a system in which different crops are grown together at the same time on the same area of land. There are other forms of this system such as relay cropping, which has a marked time of planting component, and multiple cropping, in which more than one crop harvest per season is obtained.

A study conducted in northern Nigeria by Norman (1971) showed that, in general the profitability of crop mixtures over sole crops was about 60 percent This particular study was conducted on locally grown annual crops under indigenous conditions. Under improved technological conditions, the superiority of inter-cropping as a farming system has also been demonstrated (Aukland, 1970; Evans 1960 and 1962; and Radka, 1968).

With the serious research efforts being placed today on crop production within the framework of a farming system, renewed interest has been generated in mixed cropping. Fisher (1972) has reviewed mixed cropping from a plant physiologists' point of view and Norman's study (1971) covers the social economic considerations. As a cultural practice, the reasons for the popularity of intercropping among small farmers in tropical environments have been summarized by Finlay (1976) as follows:

(i) Flexibility: Sowing and planting dates can be arranged so as to optimize labour requirements during cultivation and harvesting (Ruthenberg, 1971).

(ii) Profit maximization: Higher output with higher yields per unit area of land (Norman, 1971 ; Ruthenberg, 1971).

(iii) Resource maximization: On a given area of land, mixed cropping maximizes the returns from the most limiting factors. In considering that the chief constraint for a small farmer who used hand tools is his own labour, and, in some cases, land area (Ruthenberg, 1971), the importance of receiving maximum return from these two inputs add merit to a mixed cropping system.

(iv) Risk minimization: Insurance against insects, diseases, weather and price fluctuation.

(v) Soil conservation: Utilizes the benefits of a long period of ground cover to protect the soil from water and wind erosion. Yields of soybean increased 20 to 25 percent using maize as a temporary windbreak in a mixed cropping system (Radka, 1968).

(vi) Soil fertility maintainance: Higher retension of soil fertility with nitrogen fixation by legumes, root excretions, mycorrhiza effects, roots feeding at different levels and over different periods of time and adaptation of planting to changing soil conditions are all important factors in an intercropping soil management system.

A true sorghum monoculture in northern Nigeria resulted in a dramatic yield depression from the first to the second crop, after which yields declined gradually. This drop in yield could be avoided by mixed cropping (Goldsworthy and Watson, 1960).

(vii) Weed control: Grain legumes where well grown with early weeding because of their relatively slow early development, can, after 4 to 6 weeks,

act as a smother crop with a closed canopy (Auckland, 1970). Crop competition is the cheapest and most useful method the small farmer has to control weeds.

(viii) Nutritional reasons: A continuous supply of varied foods over several months, with balanced nutrition, can be partly achieved through a mixed cropping system. Frequency of consumption depends partly on storage, which is generally a problem. In many parts of Africa, soybeans will store better than any other grain legume (Ruthenberg, 1971).

Disadvantages of intercropping and relay cropping include:

(i) Most intercropping and relay cropping is difficult to mechanize and thus hard to carry out on a large scale.

(ii) Pest control in intercrops using chemicals may be difficult because of the differential reaction of the two species to the chemical and because of physical obstruction.

5.2 Factors affecting productivity in mixed cropping systems.

To get maximum production from an intercrop system, we need to understand the main factors that determine growth of crops in mixtures. Plants growing together compete for light, water and nutrients, and there may also be chemical interactions between them. Light competition arises when one crop is taller than the other. Competition for nutrients is greatest in a relay crop situation, when one crop is planted into soil already depleted of nutrients by the earlier planted crop. Competition for soil moisture is an important factor in areas of limiting soil moisture. For maximum production, it is necessary to adjust the factors that determine the degree of interaction between species, such as:

(i) Time of sowing of the crops

(ii) Spacing of the crops

(iii) Nature of the crops

(iv) Nature of the varieties of each crop

These factors must be adjusted so that competition for light, water and nutrients between the species is minimized and the cropping system fits into the climatic and economic constraints imposed on the farmer. To illustrate these points, examples will be used from intercropping of cowpea and maize studies at IITA, (1978).

(i) Time of sowing: The shorter the overlap period between the crops, the closer the cowpea yield will be to the monocrop cowpea yield (Tables 5.1 and 5.2).

Table 5.1: Effect of planting time on yield of cowpea when intercropped

Planting date		Cowpea Yield	Kg/ha
Cowpea	Maize	% of monocrop	
April 19	25 days later	79%	1420
"	Same time	43%	768
25 days later	April 19	40%	515

Table 5.2: Cowpea yields as affected by planting date relative to the maize in cowpea - maize intercrops. (Maize population 30,000-33,000 plants/ha).

Treatment	Yields of cowpea kg/ha Monocrop	Intercrop	% of Monocrop
1975			
Same time	1140	420	37
1 month later	670	50	8
1976			
2 months later (a)	1440	410	28
(b)	1325	612	46
(c)	998	54	5

Planting cowpea at least 2 weeks before maize would seem the best way for allowing it to grow without being shaded by maize during most of its growth However, in the absence of irrigation facilities, farmers are generally reluctant to grow a cereal after a legume. Planting cowpeas and maize at the same time allowed the cowpea to grow without shading during most of its vegetative stage but after flowering it was shaded severely resulting in yield losses between 58 and 75 percent (Nangju *et al*. 1978). Planting cowpea one month after maize was the worst choice since cowpea was shaded throughout most of its growth resulting in almost complete crop failure. Planting cowpea one month before the harvest of a cereal crop would have been a better alternative except that this arrangement would require a long rainy season which is not feasible in the bimodal region in Western Nigeria.

(ii) Spacing of the crops: The fewer the maize plants, the less the competition and the higher the cowpea yield (Table 5.3).

Table 5.3: Effect of maize population on cowpea and maize yields in intercropping.

Maize population	% Light transmission	Cowpea yield kg/ha	Maize yield
0	100%	1098	0
10,000	66	700	2775
20,000	47	556	4365
30,000	37	432	5131

Nangju *et al* (1978) showed that row spacing of 75 to 100cm was not adequate to prevent cowpea from climbing maize. However, row spacing of 150cm was fairly effective in preventing the crwpea from climbing over the maize

plants provided they were planted between rows instead of within the same rows or hills with maize. Maize yield was reduced under intercropping when cowpea climbed over the maize plants as a result of increased lodging and decreased photosynthetic leaf area exposed to solar radiation.

(iii) Nature of the crops.

The selection of an appropriate plant type of cowpea for intercropping is important from two points of view: (a) certain plant types cause more yield reduction to maize than others, and (b) certain variety or plant type can maximize the utilization of available light under the maize canopy and/or tolerate a certain degree of shading more than others. An ideal plant type or cultivar for intercropping with a cereal could be one that does not have a climbing tendency even if they are planted near each other, has the ability to quickly spread over the ground to intercept all the available light under the maize canopy, thus assisting in weed control as well, and can tolerate shading during vegetative and/or reproductive stage. Between the erect and spreading cowpea cultivars the spreading cultivars such as TVu 3231-1-1 would be more appropriate for intercropping since they have greater ability to utilize the available sunlight under the cereal canopy than do the erect cultivars such as Prima and TVu 4552 (Nangju *et al.*, 1978).

(iv) Influence of crop varieties:

An early, short season and small maize variety will normally shade the cowpea less, and result in better cowpea yields than a taller, full season maize variety (Table 5.4).

Table 5.4: The influence of maize variety on maize and cowpea yield in an intercrop, both species sown at the same time.

Maize cultivar	Seed yield (kg/ha)			
	Cowpea		Maize	
	Monocrop	intercrop	monocrop	intercrop
Upper Volta Early	2585	1282	2026	1979
TZPB	2600	803	6101	6542

Some cowpea varieties are better suited to intercrop conditions than others, but the farmer must choose whether cowpea yield is obtained at the expense of maize yield, such as when climbing varieties are used (Table 5.5).

Table 5.5: Effect of cowpea plant type on cowpea and maize yields when both were planted at the same time in an intercrop experiment.

Cowpea variety	Seed yield (kg/ha)			
	Cowpea	% monocrop	Maize	% monocrop
Prima (erect)	127	22	4100	104
Pale Green (semierect)	603	33	2516	63
Pole Bitao (climbing)	507	69	2678	68

5.3 Soybeans:

Data on intercropping soybean with other crops in Africa is lacking and it would seem that research on this aspect is urgently needed to generate information on which basic recommendations for farmer adoption can be based. Finlay (1976) has demonstrated that under conditions in Eastern Tanzania, a soybean - maize intercrop was superior to a monoculture crop of cereals (Table 5.6).

Table 5.6: Intercropping of three cereals and twelve soybean cultivars showing mean grain yield in (tons/ha).

	Monoculture	With Maize	With Sorghum	With Millet
Percentage of monoculture (soybean)	100	37	43	18
Mean cereal only		2.94	1.33	3.47
Total cereal - Soybean		3.50	1.98	3.75
Check - cereal monoculture		3.09	1.36	2.89

Studies for crop production recommendation, such as time of planting, plant population, seeding rates and row width, planting depth, need for inoculation, fertilizer rates, pacement and time of application, pests and disease control, harvesting and storage procedures for a soybean intercrop are urgently needed in all environments where soybean can be grown in Africa. If soybean is to become accepted as a basic food commodity or cash crop or both on the Africa continent, in terms of nutritional or economic improvement among the majority of African farmers, then we have to devote more resources to research so that it can be incorporated successfully within the farmer's own crop production system.

In tropical and sub-tropical Asia intercropping of rice and soybean is used when the period between rice crops is too short for a full season soybean crop. Farmers using this technique, plant soybeans in rows before the rice is harvested. Green pods are harvested and sold as a vegetable crop. Grain soybeans can also be cultivated using this method if sufficient

time is available for the pods to mature. Here again, precious time is saved by planting before the rice harvest. Generally, no significant reduction in rice yield is encountered if soybeans are planted 15 days before the rice harvest. However, in Indonesia farmers broadcast the soybeans in the rice field before the harvest of the rice crop. Because of poor germination and the use of poor cultural practices, yields are only 0.5 ton per hectare (Somaatmadja, 1972).

Soybeans are sometimes cropped following or interplanted with other cereal crops, such as corn and barley (Dalrymple, 1971), oats (Pandleton and Hartwig, 1973), and sorghum (Cheng, 1972). In one system used in Taiwan, one row of corn or sorghum is planted for every four rows of soybeans. In southern Taiwan the combination of corn and soybeans netted the highest returns even though the soybean yield was 35 to 65 percent below pure stand yields (Chao, 1975). Soybeans minimize weed growth, provide additional income, and reduce soil erosion. Four rows of soybeans can be planted between the newly planted banana stalks during the first year (Hung, 1974). In the Philippines and Sri Lanka soybeans have been interplanted in mature coconut plantations (Herath, 1975). In Malaysia trial plantings have been made between young rubber and oil palm trees. In Taiwan several legume crops, including soybean, peanut, and mung bean, are sown between rows of newly planted or recently ratooned sugar cane.

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CHAPTER SIX

MINERAL NUTRITION

6.1 Introduction

The general nutritional requirements of cowpeas are similar to other crops except that their potential for symbiotic assimilation of atmospheric nitrogen reduce the demand for mineral nitrogen and create special demands for molybdenum, cobalt, boron, copper, phosphate and zinc (Summerfield *et al.*, 1974).

Cowpea generally does not respond to fertilizers in newly-cleared soils or on soils of moderate to high fertility levels, but significant responses have been obtained in poor soils and in soils continuously cropped without fertilizers (Nangju 1975).

6.2 Nitrogen and nodulation.

Nitrogen is generally concentrated in the leaves during vegetative growth, becoming localized in the seed towards maturity (Jacquinot, 1967). It has been reported that in field situations, seed inoculation with *Rhizobium* is seldom necessary, as strains capable of causing nodulation are indigenous in soils in cowpea growing areas (Sellschop, 1962). Several factors affect the degree of nodulation in cowpea. Nodule production in cowpeas in Malaya was trebled by mulching and significantly increased by watering, but was decreased by repeated cultivation (Masefield, 1957). The degree and effectiveness of nodulation also increased by application of P (Tewari, 1965), by mulching (Masefield, 1957; Terada, 1971) and by low N during early seedling

growth (Dart, 1973, Ezedinma, 1964; Pate and Dart, 1961). Nodulation is great ly influenced by photoperiod (Doku, 1970; Tewari, 1966). Longer days (photoperiods of 16 hours) reduce nodulation even when water is not limiting (Doku, 1970).

An estimate of the amount of N fixed annually by cowpea is given as between 73 and 240 kg/ha by Nutman (1971). The fixation of N by pot-grown plants in Australia was restricted in the presence of ammonium sulphate, especially during the autumn, although urea, used as fertilizer at sowing or as a foliar spray during growth stimulated fixation (Dart and Wilson, 1970). Primary root nodulation was significantly affected by temperature, ammonium nitrate and light intensity, with an optimum temperature of 24°C. Secondary root nodulation, with an optimum temperature of 33°C, was almost the reverse of the primary nodulation pattern (Dart and Mercer, 1965). Ezedinma (1964) recorded a stimulation of symbiotic N fixation in the presence of light dressing of N, but in the absence of seed inoculation (i.e. a stimulus of the indigenous population); on the other hand fixation equivalent to 73 kg N/ha was recorded for inoculated plants in Brazil (Gargantini and Wutke, 1960).

According to Oke (1976) about 30-4o percent of the nitrogen of cowpea crop remains in the root system and can become available for the subsequent crop. In areas where soils are very deficient in nitrogen small additions of fertilizer N can increase yield even in well-nodulated cowpeas.

6.3 Phosphorus.

The general level of application of P for cowpea production in the USA has been reported as being between (112 and 224 kg/ha) of superphosphate.

Seed yield in Egypt were also shown to be significantly increased by superphosphate broadcast prior to cultivation (Salam *et al.*, 1968). Absorption of P occurs principally at the end of the growth period, the seeds being the major sink (Jacquinot, 1967). A combination of low P application (22 kg P_2O_5/ha) with no additional N produced the highest number of nodules/plant in field trial in Ghana (Tewari, 1965), whereas foliar applications of P_2O_5 (30 kg/ha) coupled with the same quantity applied to the soil at sowing have produced by far the best results in India (Anon, 1971). Application of phosphorus between 15 and 90 kg/ha of which 50% was given as a foliar spray produced 25-98% more gain than when all the P was added directly to the soil. In experiments in northern Nigeria reported by Steele (1972), the response of cowpeas to levels of superphosphate fertilizer in field trials was confounded with the effects of post-flowering insect pest damage and it was concluded that no useful information could be obtained from such work until efficient pest control measures were developed.

Cowpea has vascular - arbuscular mycorrhizae present in the root system. The mycorrhizae are believed to improve growth by extending the root surface, so that the plant becomes a better collector of phosphate and other slowly diffusing ions in short supply.

6.4 Potassium.

Experiments carried out in eastern Nigeria have shown that cowpeas respond slightly to the application of K at rates up to (40 kg K_2O/ha) by an increased production of effective root nodules (Tewari, 1965). Other investigations in tropical Africa have shown that this element was mainly localized in the

stem during vegetative growth and later in the seeds. The seeds of higher yielding cultivars had a lower K content than those from less productive types (Jacquinot, 1967).

6.5 Calcium.

The nutritional effect of added calcium is often difficult to separate from its liming effect, which neutralized toxic elements or increased the availability of certain other elements in the soil. The optimum pH range for cowpeas lies between pH 5.5 and 6.5 (Ignatief and Page 1958). Acid soils apparently inhibit nodulation by *Rhizobium*, which may lead to N deficiency. The effect of liming on nodulation depends on the cowpea variety. Varieties VITA-1, TVu 1977-OD and TVu-4552 gave a large response in both nodulations and growth when limed. Varieties Ife Brown, TVu-4557 and VITA-3 showed a small-to-moderate response in nodulation when limed (Kang *et al*, 1977) Jacquinot (1967) reported that the balance between K, Ca and Mg cations depended principally upon the age of the plant, the relative proportions remaining almost constant in the roots and stems but changing markedly in the leaves, primarily due to a loss of K and a progressive accumulation of Ca. Most of the calcium is taken up during the first 40 days of growth but it may accumulate in the leaves in replacement of potash during later growth (Jacquinot, 1967).

6.6 Magnesium.

Jacquinot (1967) found that the rate of Mg uptake increased during the growth of a range of tropical cultivars and was greatest during the latter third of the growing season. Foliar concentrations were higher in the more

productive types but the final concentrations in different organs showed no significant overall variation. Specific responses to Mg applications, in terms of vegetative growth or seed yield, are not known to have been reported.

6.7 Sulphur.

Although cowpeas require only small quantities of sulphur, this nutrient is known to be deficient in many parts of tropical Africa (Kang *et al.*, 1977). A definite response by cowpea to sulphur has been found in greenhouse experiments conducted at IITA (Luse *et al.*, 1975) where three varieties were grown in pots with sulphatic - S in soil solution maintained at seven different concentrations from 45 ppm S to near zero (where only deionized water was added). Seed yield and seed S content of cowpea increased as the level of added soil solution S increased from near zero to about 2 ppm and then tended to remain nearly constant at higher soil S concentrations. These results imply that to attain maximum yield of cowpeas in the tropics, sulphur fertilization will be required in many areas. The S concentration in rain water falling in northern Nigeria during the high rainfall months is about 0.2 ppm (Bromfield, 1974), a level far below adequacy for either good yield or high seed S content.

6.8 Trace elements.

There is a marked lack of published information on the effects of trace elements on cowpea growth and seed production. An application 224 kg/ha of molyBdenized superphosphate every 5 years is recommended in South Africa as beneficial for cowpea nodulation (Muller and Sellschop, 1954).

Whyte and Trumble (1953) gave a general requirement for Mo of between 20 and 50 g/ha for legumes and also stated that Mn, Cu, Zn, and B are essential in extremely small quantities for effective nodulation and increased seed yield. These authors however, do not specifically refer to cowpea and, indeed, there was no observed increase in seed yield following application of trace elements in field trials in Western Nigeria (Ojomo, 1967).

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CHAPTER SEVEN

WEED CONTROL

7.1 Introduction

Weeds compete mainly for light, nutrients and water and as a result crop yields may be greatly reduced. In areas where shifting cultivation is practised, weed growth is generally low and little weeding may be required the first year after clearing (Landetot, 1958). However, with continued cultivation, there is a rapid increase in weeds particularly grasses (Moody, 1973a) and since the farmer is unable to control these, he abandons his land and moves to a new area (Moody, 1973b).

Major weeds occuring at IITA which could seriously reduce the yields of cowpeas are: *Digitaria horizontalis, Brachiaria deflexa, Setaria longiseta, Eleusine indica, Chloris pilosa, Talinum Triangulare, Ageratum conyzoides, Spigelia anthelmia, Synedrella nodiflora* and *Euphorbia heterophylla* (Moody, 1973b).

In addition to reducing crop yields, weeds can act as alternate hosts for insects, diseases and nematodes. Of 39 weed species sampled at IITA only two, *Euphobia heterophylla* and *Trianthema portulacastrum*, were found to habour no endoparasitic nematodes (Afolami and Caveness, 1973). When cowpeas were not weeded insect damage to the developing seed increased by 15.8 percent when compared with results obtained with weed free plots (Moody, 1973b). Maximum yields will be obtained when grain legumes are grown without any weed competition. If this can not be achieved, weed control in the early growth stages of the crop is

essential, as the most serious effects from weed competition generally occur during the first third of the life cycle of the crop. At IITA, cowpeas kept weed free for 25 days after emergence yielded only 5% less than those that were kept weed free throughout their life cycle. An average reduction of about 11 percent occured if the cowpeas were weeded once 3 weeks after emergence. Yield losses were negligible if the crop was weeded twice i.e. 1 and 4 weeks after emergence (Moody, 1973b).

7.2 Methods of weed control.

(i) Row width: This is an important cultural parameter in any weed control program. Four plant types of cowpea were planted at two-row spacings (50 and 100cm) and subjected to three levels of weed infestation (no weeding, 10-day, and 20-day weed free periods). No weeding resulted in no yields at all spacings and in all four cultivars. The main weed species was *Euphorbia heterophyla* plus a few grasses (IITA, 1976).

Weed weight and cowpea seed yield were significantly affected by spacing and duration of the weed free period (Table 7.1). Semi-erect, broad-leaved VITA-1 was the most competitive, and semi-prostrate VITA-5 the least competitive against weeds. The erect leafy TVx 1836-19E and TVx 33-1G were intermediate between the two cultivars in their response to weeding. Apparently the height of the leaf canopy influenced the ability of cowpea to suppress weed growth, particularly at wide spacings, more strongly than leaf shape and size.

Table 7.1: Effect of spacing and weed free period on weed weight at 64 DAP and seed yield of four cultivars of cowpea planted first season, 1978

Cultivar	Weed dry weight (kg/ha)		Cowpea seed yield (kg/ha)	
	10 DWP*	20 DWP**	10 DWP	20 DWP
	Spacing:20x50cm			
TVx 1836-19E	711	176	978	1216
VITA-1	346	116	443	837
VITA-5	1038	250	319	1357
TVx 33-1G	612	270	1069	1356
	Spacing:20x100cm			
TVx 1836-19E	1057	404	890	1231
VITA-1	596	211	487	958
VITA-5	1134	845	449	1307
TVx 33-1G	1057	307	1163	2499
S.E. ±	447		117	
C.V.	21		25	

* DWP = 10 days weed free period.

** DWP = 20 days weed free period.

Mechanical cultivation or hoeing is probably the most practical means of keeping cowpea fields free of weeds during the first 30 days after planting.

Narrow row spacings have been reported to be more effective in suppressing weed growth than wide row spacings (Kust and Smith, 1969; Wax and Pendleton, 1968). As row spacing decreases, fewer interrow cultivations and lower rates of herbicides are needed to achieve comparable weed suppression (Burnside, 1972). However, cowpea cannot be grown at

extremely narrow spacings as this can result in yield loss due to lodging and/or interplant competition. Furthermore, the use of narrow spacings can make interrow cultivation impractical, although this may not be a problem for the majority of small farmers in the tropics because they do not have the equipment for it.

(ii) Hand weeding:

This method is used mainly for removal of weeds within the rows of crops where the hoe or other cultivating implement cannot reach. It is too slow a process to be used on a large scale and in addition it is usually delayed until the weeds are large enough so that the farmer can grasp them easily to pull them out. By the time they reach this stage they may have caused considerable damage to the crop through competition.

(iii) Hoe weeding:

The hoe is the most widely used means of weed control in the tropics. It is an effective means of weed control but it is tedious, expensive and requires much labour. It has advantages over hand weeding in that it is a much quicker operation and can be carried out at an earlier stage in the growth cycle of the crop. Often the farmer removes the weeds from within the row by hand at the same time he is hoeing. Unfortunately, by the time many farmers start hoeing their fields, the weeds have already had a deleterious effect on the crop.

(iv) Interrow cultivation:

Weeds within the row may be difficult to control by this means and it may be necessary to remove them by hand or hoe. Timely cultivation

is sometimes not possible due to adverse soil or weather conditions. Also in very wet conditions tillage machines often only remove weeds from side to side between the rows without killing them.

(v) Herbicides:

These can be applied either before crop and weed emergence so that their residual effect will last until the critical period of weed competition has passed or post emergence when the weeds start competing with the crop. One of the main advantages of herbicide treatments is that they are rapid. Chemical methods of weed control are more attractive and acceptable for large scale farming where labour is inefficient and inadequate (Orsenigo, 1970). However, in many parts of the tropics increasing labour costs and the unavailability of labour at critical times are rapidly causing the use of herbicides to become more economical than hand labour even on small farms (Furtic, 1970).

One of the greatest restraints on the introduction of herbicides to small scale peasant farming is the cropping pattern presently used. Cowpeas are rarely grown as a sole crop; the majority being grown in association with maize and sorghum (Anon, 1972) and also interplanted with yam (Oyenuga,1967). Several herbicides have been tried with some degree of success in different places. Herbicides that have been identified as giving good weed control with excellent crop tolerance in cowpea are fluorodifen, trifluralin, metolachlor, DCPA, mixtures of metalachlor or trifluralin with metobromuron (Akobundu, 1978).

7.3 Herbicide application.

Herbicides are usually applied in such small amounts that they must be combined with a liquid or solid carrier in order to be applied evenly during application. For effective weed control, uniform distribution of the herbicide is essential. To achieve this, the area to be treated and the amount of herbicide to be used must be measured accurately. Most herbicides contain some inert material in addition to the active material and as rates are usually expressed in terms of active ingredient (a.i.), adjustments have to be made when determining the amount of herbicide to be applied. The following formulae can be used to determine the amount of herbicide needed to cover a given area:

(i) For solids:

$$\frac{\text{Rate in kg a.i./ha} \times 100}{\text{\% a.i. of solid}} = \text{kg product/hectare}$$

(If rates are expressed in lb/ac to convert to kg/ha multiply by 1.12)

(ii) For liquids.

$$\frac{\text{Rate in g a.i./ha}}{\text{Concentration in g/L}} = \text{litres of product/hectare}$$

Granular herbicides are rarely used for weed control in grain legumes. They are easier to apply but are more expensive, usually less effective and uniform application is difficult to achieve especially on small plots. Therefore, the majority of herbicides are applied in liquid form with the aid of a sprayer.

Many sprayers are available for application of herbicides to a cowpea crop. These range from the knapsack sprayer which can be fitted with a pressure regulator, to a tractor mounted sprayer . Descriptions of these and their method of operation are given in a number of publications

(Fryer and Evans 1908; Furtick and Romanowski, 1971; and Wilkinson, 1972). Regardless of the type of sprayer used it needs to be calibrated to ensure that enough water (or other diluent) is used to uniformly cover the field. When mixing sprayer solutions, never place the herbicide in the spray tank ahead of the diluent because wettable powders tend to float and many emulsifiable concentrates are acidic. Always fill the tank with one-quarter to one-third the required amount of diluent, add the herbicide, then add the remainder of the diluent. Wettable powders should be mixed (soluble powders should be dissolved) with a small amount of diluent before adding them to the tank as this makes dispersion of the powder in a larger amount of diluent easier. If a herbicide mixture is to be applied, add each of the components to the spray tank separately. Do not mix them prior to addition. If different types of compounds are to be mixed add emulsifiable concentrates first and then follow with wettable powders.

When applying herbicides always wash the sprayer between treatments except when the same compound is being used at different rates. In this instance, apply the lowest rate first. To reduce the possibility of contamination between treatments spray the compounds that are easiest to remove from the spray tank first. Thus soluble salts should be sprayed before wettable powders with emulsifiable concentrates last.

7.4 Incorporation of herbicides.

Sometimes it may be necessary to incorporate the applied herbicide into the soil either to reduce losses due to volatilization or to bring the herbicide in direct contact with the germinating weed seeds.

Depth of incorporation varies with the herbicide being used, the soil type and the conditions at the seedbed but 5 to 8cm is usually adequate. Irrespective of the depth or method of incorporation thorough mixing of the herbicide throughout the soil must occur otherwise weed control will be reduced. Incorporation may not be a desirable practice on soils that are subjected to structural break down under highly erosive rains.

7.5 Factors affecting herbicide performance.

The performance of a herbicide may be greatly affected by a number of factors. These include:

(i) Previous crop and treatments

(ii) Soil (a) % clay, silt, sand
(b) % organic C.
(c) pH.
(d) % Fe_2O_3
(e) tilth at time of application
(f) moisture at time of application

(iii) Rainfall (a) last (date and amount) prior to application
(b) first (date and amount) after application
(c) amount in the week following application

(iv) Temperature and humidity at time of application

(v) Wind direction and speed at time of application

(vi) Light intensity at time of application

(vii) Crop and weeddstage of growth at time of application

(viii) Method and depth of incorporation

(ix) Length of time between application and incorporation

Because of the number of variables that can affect the performance of herbicide, promising formulations should be tested over several years in different seasons at several different locations before being recommended for general use.

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CHAPTER EIGHT

PRINCIPLES AND CONCEPTS IN PLANT BREEDING

8.1 Introduction.

Plant breeding is the art and science of changing and improving the heredity of plants. The art of plant breeding lies in the ability of the breeder to observe plants differences which may have economic value. Early man guided evolution of crop plants by propagating the progenies of good looking plants but he had no knowledge of scientific principles. Plant breeding has been established on a scientific basis only since the turn of the century when Gregor Mendel's paper describing the laws of heredity was re-discovered. A brief review of basic concepts is given below:

8.2 The cell:

This is the smallest unit of life. All living organisms are composed of these basic units which range from simple unicellular structures of bacteria and protozoa to complex structures of plants and animals. The generalized plant cell (Fig. 8.1) is composed of a cell wall, cytoplasm and nucleus.

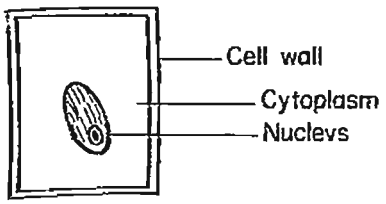


Fig. 8.1: A Generalized plant cell

However, the parts of the cell are far more complex than indicated. Sexual reproduction involves the production of gametes (Gametogenesis) and their union (Fertilization).

Gametogenesis only occurs in specialized cells of the reproductive organs. Gametes contain half the number of chromosomes (haploid number (n.). Consequently, the number of chromosomes must be reduced by half during gametogenesis. This reduction division is called MEIOSIS. In higher plants Meiosis takes place only once in the life cycle, that is, in the flower just before seed formation. Thus meiosis occurs in anthers to produce pollen grains and in ovary to produce eggs. Cells multiply through a process known as MITOSIS.

8.3 Fertilization.

This is the union of male and female gametes to restore the chromosome number characteristic of the species. In higher plants, the anthers dehisce to release pollen grains which come in contact with the stigma either naturally or artificially. The pollen grain wall splits and a pollen tube penetrates the receptive stigma and grows down the style. The pollen grains and egg cell nuclei both of which have half the chromosome number and gene complements unite to produce the embryo mother cell with the chromosome number characteristic of the species. Each embryo mother cell undergoes repeated mitotic division to form the embryo which is contained together with other tissues in the seed. Following the germination of the mature seeds, further mitotic divisions lead to the mature plant.

8.4 The Gene:

The heredity units which are transmitted from one generation to the next are called genes. Genes reside on a long molecule called deoxyribonucleic acid (DNA).

The DNA, in conjuction with a protein matrix, forms nucleo proteams and becomes organised into structures with distinct staining properties called chromosomes found in the nucleus of the cell. The behavior of genes is thus paralled in many ways by the behavior of chromosomes in which they are a part. A gene contains coded information for the production of proteins. DNA is normally a stable molecule with the capacity to form self-replication. On rare occasions a change may occur spontaneously in some part of DNA. This change called a mutation, alters the coded instructions and may result in defective protein or halfing protein synthesis. The net result of mutation is often seen as a change in some other measurable attribute of the organism called a trait. Through the process of mutation a gene may be changed into two or more alternative forms called alleles. Each gene occupies a specific position on a chromosome called gene locus. Thus, all allelic forms of a gene are found at corresponding positions of genetically similar chromosomes.

8.5 Categories of genes.

There are basically two main categories of genes:

(1) Major genes. These are genes which have a distinct effect on plant appearance and their expression is normally not influenced by the environment and their inheritance can be followed in breeding tests. In cowpea, such genes control leaf shape, colour pattern on flowers and seeds, resistance to most diseases and male sterility etc. Such genes can be used as markers in a breeding programme. Variation of such characters is qualitative.

(ii) Polygenes: These are genes whose individual effect on the appearance of the plant is small and are considerably modified by the environment so that distinct classes are not produced. The inheritance of individual genes cannot be followed in breeding tests and require more sophisticated experimental techniques than those used to handle major genes. Many economic traits fall in this category. The variation of such traits is quantitative.

8.6 Laws of inheritance:

(1) Terminology: PHENOTYPE: This is the external appearance of an individual or plant which is determined by its genetic constitution and its environment.

GENOTYPE: All genes possessed by an individual constitute its genotype.

HOMOZYGOUS: Union of gametes carrying identical alleles produce a homozygous genotype.

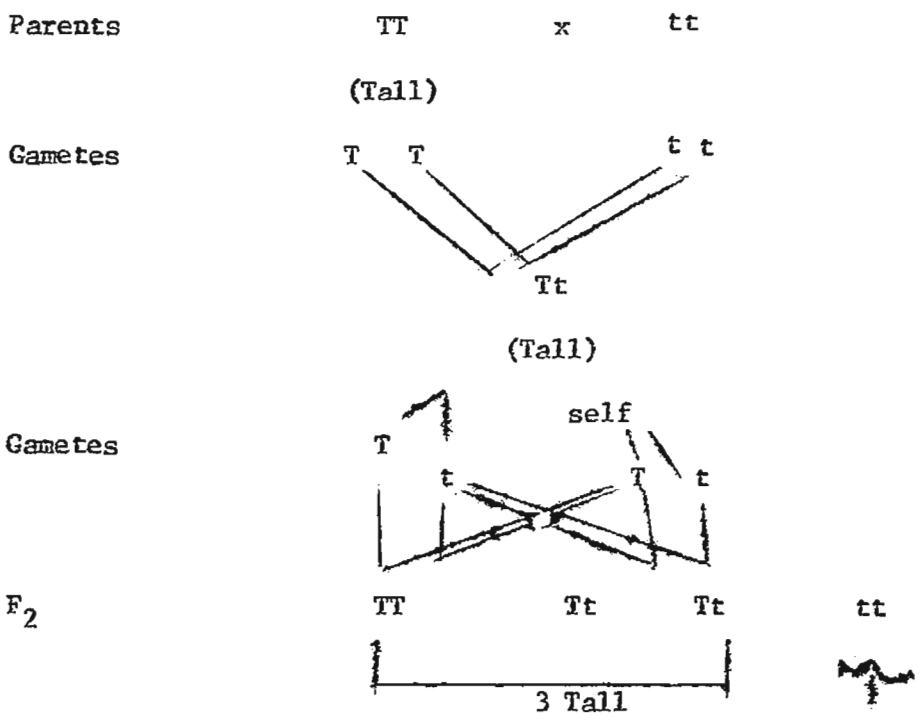
HETEROZYGOUS: Union of gametes carrying non-identical allel e result in a heterozygous genotype.

DOMINANT AND RECESSIVF ALLELES: When a pair of alleles come to phenotypic expression only in the homoxygous genotype, the allele is said to be recessive while an allele which phenotypically expresses itself in the heterozygote as well as in homozygote is dominant. These terms can be illustrated by considering Mendel's experiments.

8.7 Mendel's experiments.

(1) Mendel crossed a tall with a dwarf sweet pea by placing the pollen of the dwarf to the stigma of the tall plant and sowed the resulting seed. The plants which developed were all tall. These were then selfed and the seed

sown. This gave tall plants and short plants in the phenotypic ratio 3 tall to 1 dwarf. These results can be illustrated as follows:



The first generation after a cross is known as first Filial generation or F_1 and second generation F_2 etc. From the above illustration TT is homozygous tall whereas tt is homozygous dwarf. The resulting F_1 is heterozygous tall. Thus, tall is dominant while dwarf is recessive. In some instances the heterozygous (Tt) may be intermediate to the homozygote (TT and tt), a condition known as partial dominance. Because homozygous genotype has the same phenotype as the heterozygous genotype a <u>test cross</u> is required to distinguish between the two. The test cross parent is always homozygous recessive for all genes under consideration.

The recessive individual will produce only one type of gametes. The type of progeny in such a cross, will depend on the types of frequencies of gametes produced by the parent of unknown genotype and can help to determine the genotype of the latter. For example:

Parents:	♀ T____	x	♂ tt
Progeny			All offspring tall

this indicates that the female parent must be producing one kind of gametes and therefore, is homoxygous dominant (TT). However, if by test crossing a tall male produced tall and short offspring in approximately equal numbers the situation would be as follows:

Parents	T____	x	tt
Progeny	1 Tt	:	1tt
	(Tall)		(Dwarf)

This means that the male parent must be heterozygous (Tt). If F_1 progeny is crossed back to one of their parents, the mating is known as <u>backcross</u>. Sometimes backcross is synonymous with test cross but the backcross will be treated separately in another section. A cross in which only a single pair of alleles is considered is called a <u>monohybrid cross</u>. The above examples illustrate the simplest situation involving one gene with two alleles, one completely dominant over the other. In other cases there may be two or more alleles in the population.

(ii) For example, Mendel crossed a variety of garden peas with yellow round seeds with another variety with green wrinkled seeds. The results are illustrated as follows.

Parents	AABB	x	aabb
	Yellow		Green
	round		wrinkled
		↓	
		AaBb	
F_1		Yellow round	

When AaBb is selfed to produce F_2 the following situation results

♀ \ ♂	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb

Result:	Phenotype	Genotype	Frequency	
	Yellow round	AABB	1)	
		AABb	2)	9
		AaBB	2)	
		AaBB	4)	
	Yellow wrinkled	AAbb	1)	
		Aabb	2)	3
	Green round	aaBB	1)	
		aaBb	2)	3
	Green wrinkled	aabb	1)	1

Since two pairs of alleles are considered, this type of cross is called a dihybrid cross. If the genes are on the same chromosome they are said to be linked together and their alleles tend to remain together. Linkage among desirable and undesirable traits has got a marked influence on the rate of genetic improvement.

One principle which emerges from Mendel's crossing scheme is that there is a very rapid decrease in the proportion of heterozygous individuals with continued selfing. Thus, F_1 all will be heterozygous and in F_2 50% are heterozygous. The proportion is reduced by half on each generation of selfing.

e.g.	Generation	Proportion of heterozygotes
	F_1	100%
	F_2	50
	F_3	25
	F_4	12.5
	F_5	6.25
	F_6	3.125
	F_7	1.5625
	F_8	0.78125
	.	.
	.	.
	.	.

8.8 Quantitative genetics.

In cowpeas characters describing growth such as height, seed size, and grain yield per unit area are all quantitative. Their inheritance is

dependent upon many genes each of which contributes to the final effect. Tall plants will give tall progenies while short plants will give rise to short offspring when crosses are made between varieties. With self pollination in the generation after a cross is made, small seeded plants tend to produce small seeded progenies. If F_2 plants are harvested separately and grown as F_3 progenies, the average seed weight of the F_3 will tend to correspond with seed weights of F_2 parents. After six generations of selfing all progenies from an individual plant tend to be alike because they are genetically similar. Any difference in seed size within a plant progeny after 6 generation is mainly due to environmental variation. The growth of plants is affected by genetic as well as many factors of the environment such as nutrition, soil moisture, radiation and many others. The final yield of a variety, therefore represents two influences - a genetic effect (G) and an environmental effect (E). Thus, the phenotype (P) is the cumulative result of successive gene actions (the genotype) combined with the cumulative effects of the environment i.e. $P = G + E$. Because many gene effects contribute to the phenotype of quantitative traits such as yield, the individual gene effects cannot be measured. With two gene loci and two different gene at each 9 combinations in the F_2 giving up to 9 different genotypes as already shown above. With more than two loci affecting a trait the number of possible genotypes increase by 3^n where n is the number of loci. Thus for two loci $3^2 = 9$, 3 loci $3^3 = 27$ different genotypes, respectively.

The result is that individual gene effects cannot be measured. Only the combined effects of many genes can be measured. However, the simple principles of Mendelian genetics still apply.

8.9 Heritability.

In a cross between two pure breeding lines, the F_1 tends to be intermediate and with a similar environmental variation as the parents but F_2 will show a wider range of expression representing both genetic and environmental variations. This can be illustrated in Fig. 8.2. If the variation of parents is due to environment and if parents P_1 and P_2 were all randomized and replicated in the same field the F_2 variance (V) will equal genetic variance (VG) + environmental variance (VE) ie. VP =VG + VE.

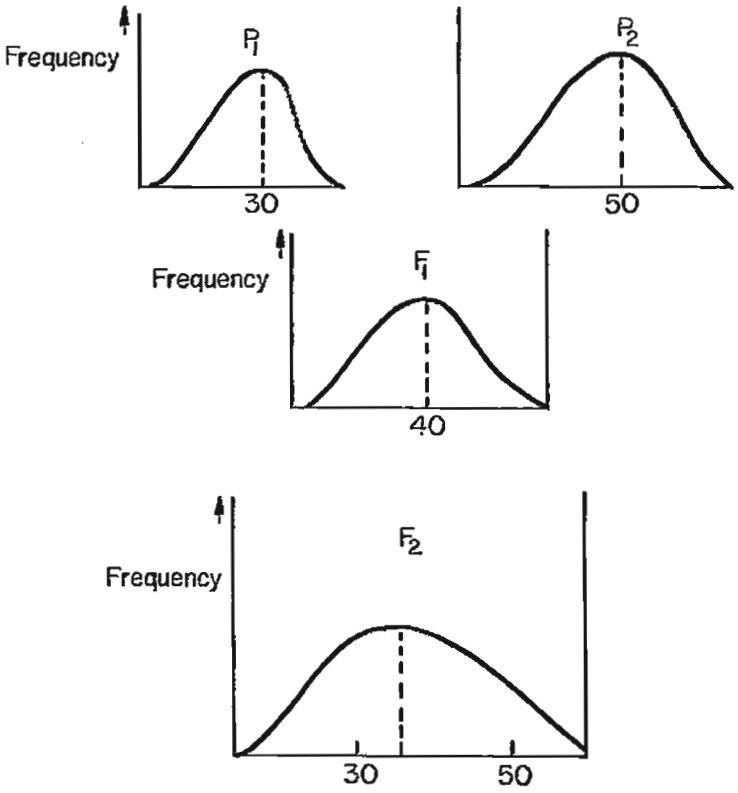


Fig. 8.2: Variation in parents, F_1 and F_2.

Subtracting the environmental variance estimated from F_1's and parents will give an estimate of genetic variance in F_2.

i.e. VP - VE = VG.

The ratio VG/VP is called heritability of the trait in a broad sense. If VE is very large, V_p will be much larger than VG and the heritability will be low. The heritability of grain yield tends to be low because many environmental factors are important besides the genetic factors. This is also a good reason why one should try to get a uniform field and management for comparing varieties for genetic differences in yielding ability. The determination of heritability is valid only for a particular combination of parents and from a particular site or season used. The determination would have to be repeated with many combinationsof parents over many different locations to obtain a general measure of heritability of a trait. It is also important to remember that the disease can affect yield, so use either disease resistantor adisease free environment to study yield heritability.

The F_1 yield may not necessarily be intermediate to that of parents. It may be closer to one parent than the other. Deviation from the mid parent value is called dominance variation. Thus, the genetic expression is a combination of additive and dominance effects. The additive effect is the genetic expression of a mid-parent value and can be thought of as the average genetic combination from the two parents i.e. VG =VA + VP. The dominance effect is only found in heterozygotes and will disappear with each generation of selfing after a cross. The additive variation on the other hand, is expressed in both homozygotes and heterozygotes and can be selected for

in each generation. Thus, the additive parts of genetic variation is more important in self-pollinated crops such as the cowpea and is of use to bhe breeder if he wants to release a true breeding variety.

eg. h^2 (narrow) = VA/VP.

The higher the narrow sense heritability the greater will the gain be from selection.

8.10 General and specific combining ability.

If a particular variety is crossed with a large number of other varieties and heights measured in F_1 and F_2 for each cross, the average effect on height of this variety over all crosses would be measured and departures from average in a particular cross would also be measured. Repeating this series of crosses in all combinations, the average effects and departures from average can be estimated for all varieties. This can be illustrated as follows:

Parent	0	A	B	C	D	E	F
0 + A			+	+	+	+	+
B		+		+	+	+	+
C		+	+		+	+	+
D		+	+	+		+	+
E		+	+	+	+		+
F		+	+	+	+	+	+

The average value of a variety is called general combining ability (g.c.a.) and measures additive genetic effects of that variety. The different

varieties will differ in their g.c.a. The non-average effects are called specific combining ability (s.c.a.) and mostly reflect dominance genetic variation. For a plant breeder it is desirable to use as parents those varieties which have high g.c.a, for a trait of interest. Note that a high yielding variety does not always give high yielding progeny. At times a breeder may not have time and capacity to measure g.c.a. and s.c.a. effects for all the parents he uses, especially as some may be disease resistant or insect susceptible. But a breeder should take note of which parents are giving many high yielding selections and should avoid those which do not even if they are high yielding. Work on inheritance, heritability, character correlation, nature of gene action and combining ability have been helpful in support of plant improvement activities.

CHAPTER NINE

COWPEA IMPROVEMENT

9.1 Introduction

Although cowpeas are widely grown, research efforts devoted to the crop have been limited compared to the staple cereal crops. Early efforts to improve cowpeas were restricted to the identification and control of insects and diseases, selection in limited collections of germplasm and hybridisation among a small number of parents. However, with the establishment of the Grain Legume Improvement Programme at IITA, cowpea breeding has received considerable attention. From the beginning, emphasis was on the development of cowpeas for the more humid tropical environments. Cowpea diseases were the most conspicuous constraints in the forest zones, thus, high priority was given to their control through host plant resistance which was recognised as the most practical solution, in view of the nature of the cropping systems of which cowpea is a part. Sources of resistance to most of the important diseases and many combined sources of resistance were identified and incorporated into breeding lines. As a consequence, genotypes are now available which have combined resistance to principal bacterial, fungal and virus diseases (IITA, 1978). Other objectives included:

- Introduction of field tolerance to pre-flowering pests especially leafhoppers (*Empoasca* spp). and thrips.
- Broaden adaptation through introduction of day length and temperature insensitivity, improve root characteristics and increase tolerance to moisture stress.

- Offer improved and high yielding plant types suitable for monoculture (erect and semi-upright strains), for mixed cropping (prostrate/ creeping) plants and vegetable types).
- Incorporation of desirable seed characteristics into improved lines e.g. medium to large seeds, white creamy or light colours, rough or loose testas for quick soaking and an adhesive quality (for akara balls).
- Establishment of a minimal schedule of chemical control of insect pests.
- Obtain information on the occurrence, etiology and pre-disposing conditions for cowpea diseases.
- Study the occurrence, life history, population dynamics and predator relationships of insect pests.
- Determine optimal plant population and spatial arrangements for different plant types and cropping systems.
- Establish time of planting, methods of planting and harvesting for different types and determining fertilizer requirements and rhizobia strains for the broad range of growing conditions.

Thus, a strategy for cowpea improvement is primarily based on breeding for high and stable yields, acceptable quality, day length neutrality, erect growth habit, early maturity, resistance to diseases and pests, and tolerance to other stress factors.

9.2 Varietal improvement.

For a successful cowpea breeding programme, it is important to understand the environment, the system of cultivation and to identify the main constraints of production. The main environmental factors may be considered under the

following headings.

(a) Climate. The main factors of climate are rainfall and temperature both of which have a profound influence on cowpea. Cowpeas tend to be adapted to semi-arid conditions and are not tolerant to water logging. Time to maturity ranges from 60 to more than 90 days depending on day-length and temperature. Clearly, improved varieties must be adapted to length of the season and at the same time the coincidence of pod development with the end of the rainy season, thus ensuring good seed quality. This means, therefore, where rainfall is restricted and uncertain, short duration types of cowpeas tolerant to drought are required. On the other hand, in areas of heavy rainfall longer duration types with heavier yield potential would be preferred. The development of such locally adapted types presents a challenge to the breeder.

(b) Soil: Generally soils tend to be low in macro- and micro-nutrients and nitrogen fertilizers are rarely applied to cowpeas. However, cowpeas are able to fix their own nitrogen but phosphate, potash, Mo, Mg are often deficient while in the low pH soils of the humid tropics Al and Mn toxicity may reduce yield. Studies have, however, shown that cowpeas are comparatively tolerant to acid and highly weathered soils of the tropical rain forests of West Africa (IITA, 1977). Studies of soil acidity complex have also shown that Ca nutrition is probably more important than Al and Mn toxicity as a factor that limits growth of cowpeas on these soils. The study has also shown that there is genetic variability in cowpeas tolerance to calcium deficiency.

9.3 Biological environment.

The biological environment comprises a full range of pests and diseases which attack the crop at different stages. These agents reduce yields of the crop considerably. Insect damage appears to be the main limiting factor to cowpea production. Chemical methods to control most insects and diseases, though available, are often expensive. Therefore to stabilize yields and reduce dependency on chemicals, a major objective of breeding must be the incorporation of disease and insect resistance.

9.4 Socio economic factors.

Consumer preferences for seed type is of paramount importance. For instance in the Savannah areas of West Africa, large white seed is preferred while in parts of Ghana and East Africa red seed is preferred. In South and Central America, black seeds are preferred. Thus, it is important to decide the extent of change which may be tolerated in the traditional systems and the nature of improved cultivars.

9.5 Improvement methodology.

The improvement of cowpeas at IITA, has largely followed the conventional lines viz: introducing and testing germplasm, recombination of desirable characters, selection, testing and release of improved materials.

(i) Collection and evaluation of germplasm.

Diversity within *V.unguiculata* is large. There is a great diversity of characters including flower colour, seed (size, colour, colour patterns) leaf (shape, size, marking), pod (size and colour) as well as variation in response to day length, temperature and, importantly, reaction to pests and diseases.

There is an extensive germplasm collection in Nigeria, India, USA, and Senegal. At IITA the germplasm bank has more than 10000 accession of *V. unguiculata* and about 150 wild species of *Vigna*. The organisation and evaluation of cowpea germplasm at IITA began in 1970 through contributions by other breeders and some systematic collecting in Nigeria and Niger. By 1974, most of the accessions had been intensively studied and sufficient information regarding botanical and agronomic characters and disease susceptibility was accumulated. A germplasm catalogue of 4,224 entries was produced in which 50 descriptors were given (Porter *et al.*, 1975). From 1977 to 1980 as a result of extensive exploration and collection in West and East Africa, the size and diversity of this collection has more than doubled. This wide genetic base is the basis on which hybridization programme can be based to enhance further improvement.

(ii) Hybridization.

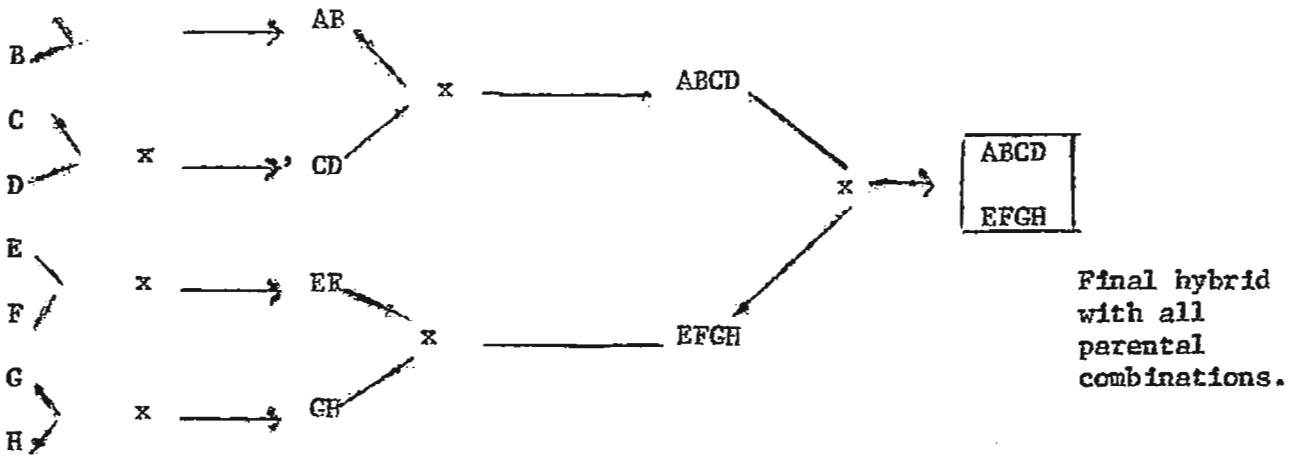
The main purpose of hybridization is to enhance recombination among genes from different genetic strains. The choice of parents is of prime importance in any hybridization programme. In many breeding programmes, yield is the primary objective. However, adaptation to stress environments, broad adaptation and resistance to diseases and pests are receiving significant attention. Because there are many factors that contribute to yield, it makes it difficult to choose parents to hybridize in a yield improvement programme, and this often results in many crosses being made. These often involve parents chosen on their ecogeographical diversity and presumed complementary characteristics.

Ideally, parents should be chosen so that progenies from hybrid combinations have a high probability of containing recombinants of value. The desired recombinants must be clear in mind and efficient methods of identifying them should be defined. The steps involved in a hybridization programme include: (a) making crosses, (b) handling the hybrid populations, (c) testing and (d) releasing the promising materials.

(a) Making crosses.

Hybridization has basically always been bi-parental. However, in most cases the characters required may not be present in only one variety. Bi-parental crosses are too restrictive to permit rapid improvement in self-fing-species like the cowpea. This can be overcome by the use of multiple crosses.

Multiple crosses involve many parents which are crossed in successive generations into single crosses, double crosses, octople crosses, diallelcrosses, chain crosses etc. eg. A multiple cross:



Advantages of a multiple cross:

(a) Genes from many sources are brought together

(b) Generates greater variation some of which may turn out to be useful.

Disadvantages:

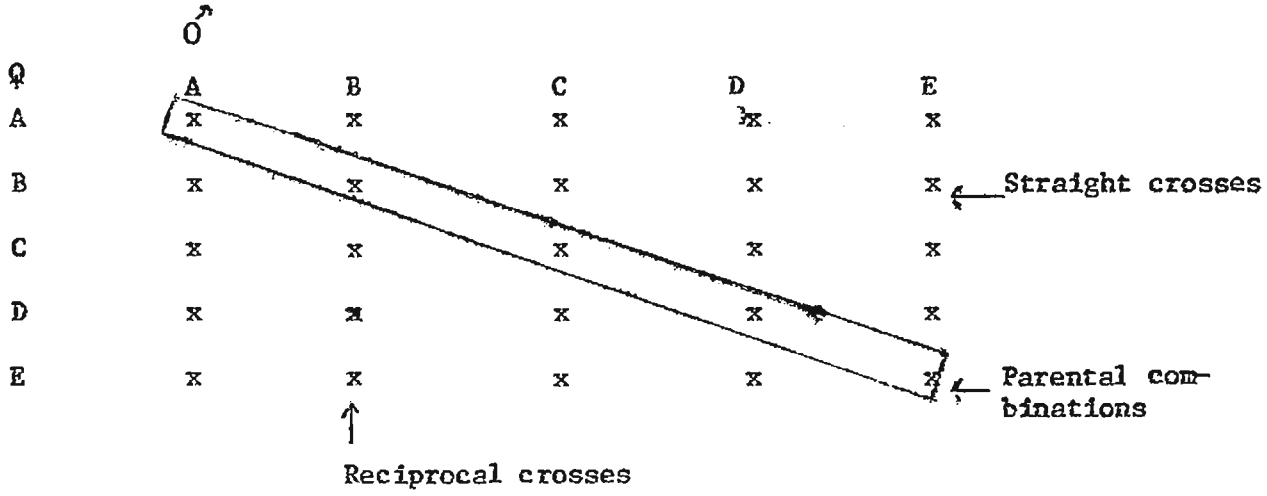
(a) The frequency of favourable alleles for different characters in an $F_1 \times F_1$ cross of diverse parents is considerably lower than in a conventional F_2 generation. For this reason, multiple crosses cannot be used for combinations of more than 10 alleles without risking loss of a large proportions of them.

(b) It may not be practically feasible in later generations to obtain enough F_1 seeds to retain all potential genes in the final crossing generation.

(c) There are chances of including unduly large numbers of unadapted strains.

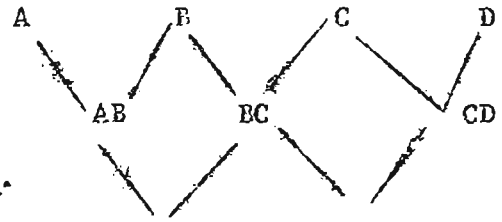
A diallel cross.

This involves crossing parents in all possible combinations, eg.



Chain crosses:

eg.



9.6 Making crosses.

Cowpeas are generally easier to cross than other grain legumes. This is because cowpea flowers are large and easy to manipulate, the keel is straight beaked and not twisted. There are only afew floral nodes per receme, which tend to have a lower rate of abortion than many other species; and 8-12 seeds are usually produced per cross. Nevertheless, conventional crossing methods are slow, insect contamination does occur especially in the field, Selective receptivity is a limiting factor and a high rate of abscission of manipulated flowers. Pre-mature flowers drop and bud abortions are greatest when the seed plant nears maturation; when the two gametes are incompatible and temperatures are high and humidities low.

A rapid and effective method of hand emasculation and crossing of cowpeas was developed at IITA (Rachie *et al.*, 1975). This consists of removing the upper half of the petals starting with a partial cut opposite the stylar and staminal section. Following pollination with a freshly opened flower the crossed bud remains uncovered. The process of emasculation and pollination can be accomplished at the rate of one to two a minute with an average of 10-12% success. Synchronizing flowering under low temperatures and high humidity conditions increases the success of hand crossing to 50%.

9.7 The technique.

Whenever possible, actual crossing should be done in a meshhouse/greenhouse. This reduces interference from insects, pests and important diseases. It also permits control of watering, staking, applying nutrients and regulating plant development. However, potted plants are small and numbers of pods per plant is low.

9.8 Mesh house.

In tropical climates an expensive greenhouse is not essential for crossing purposes. Commonly available wire mesh over a simple wood frame serves well. However, it is desirable to have a ceiling 2 to 2.6m high to permit staking of climbing types as slightly reduced light promotes the climbing tendency in many *Vigna* species.

9.9 Synchronizing flowering.

A considerable proportion of *Vigna* germplasm is day length sensitive. Inclusion of such types in the crossing programme creates problems because of synchronous flowering. Thus staggered planting of early parents particularly when used as females is usually desirable.

A delay in flowering can be achieved on a limited scale by nipping of the developing flowers and fruits or more severe pruning of the plant. New plants are easily started by putting stem cuttings with a leaf in flats of sand. Cover the flats with plastic to maintain high humidity around the developing plantlet.

The first developing buds on the plant tend to set pods more easily than later developing buds. It is desirable to remove other buds on the same receme and peduncle leaving only one for crossing purposes. This diverts all assimilates in the peduncle into one pod and avoids confusion in labeling.

9.10 Emasculation.

In all the flowers of *Vigna* species, studies under Ibadan conditions, anthesis took place just prior or simultaneously with the opening of corolla. Hence, flower buds destined to open the following morning are ready for emasculation (Fig. 9.1). These flowers buds have reached their maximum unopened size and have started to pale slightly from deep green. Emasculation and pollination can be done at almost any time of the day. Under Ibadan conditions emasculation and pollination done in the late afternoon were highly successful. Apparently cool nights provide better conditions for fertilization than the hotter day time.

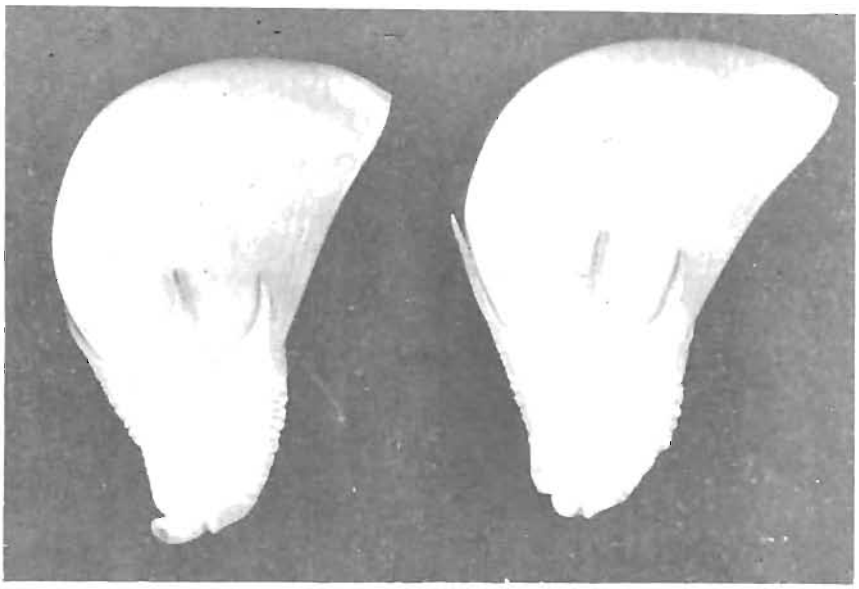


Fig. 9.1: Flower buds ready for emasculation.

The bud selected for emasculation is grasped firmly but gently to avoid any stress at the fragile attachment of the bud and receme. A cut about two thirds the width of the unopened bud is made in the centre of the bud starting from its straight edge. Small finely pointed forceps or dissecting scissors, scalpels or even long thumb-nails can be used to make the cut (Fig. 9.2). The upper portion of the folded petals is then grasped by the thumb and index finger and lifted outward tearing the upper portion of the petals free (Fig.9.3). This leaves the upper portion of the style, stigma and stamens free and exposed to facilitate removal of the 10 anther sacs with a scissor or forceps (Fig. 9.4). The scissors or forceps should be dipped in alcohol (75-95%) between crosses and the receptive green tipped stigma should not be touched prior to pollinating. This emasculation procedure should require no longer than 15-25 seconds per flower (Fig. 9.5).

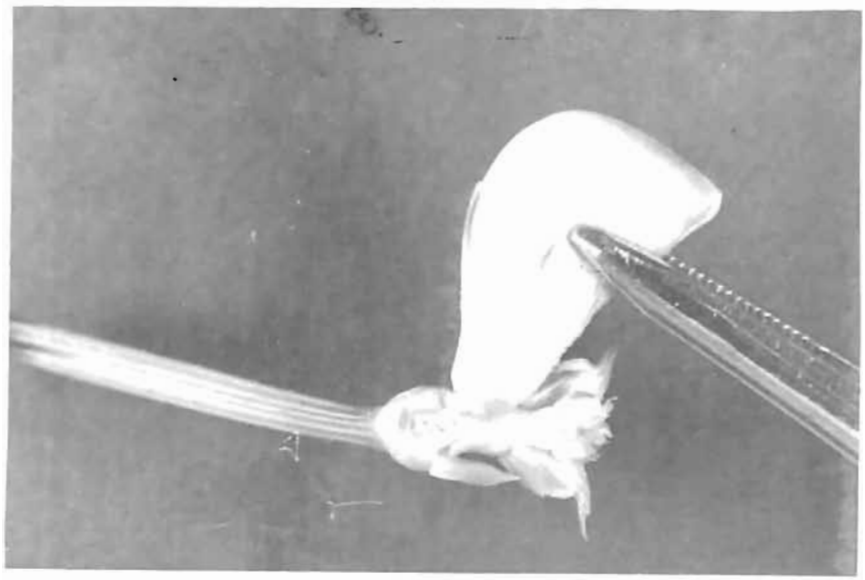


Fig. 9.2; Make a cut 2/3 the width of the bud.

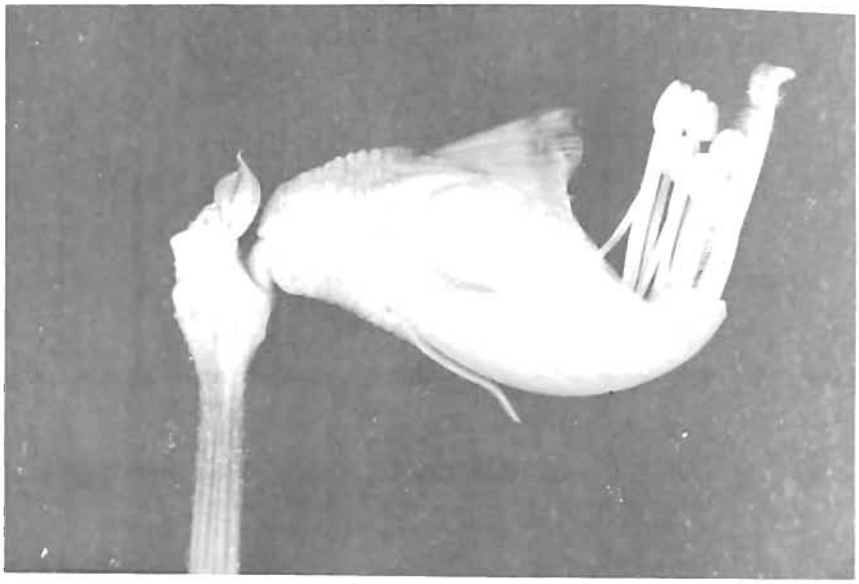


Fig. 9.3: Gently tear off the cut segment.

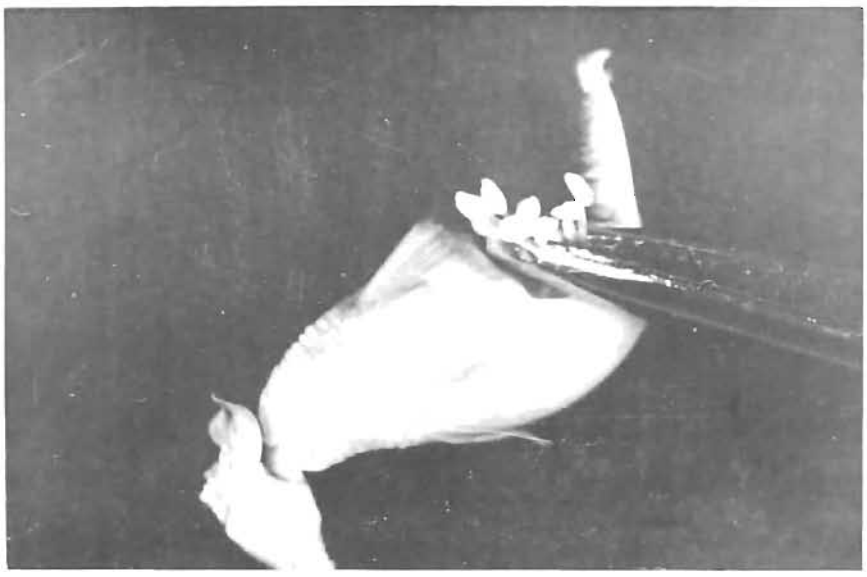


Fig. 9.4: Remove all other sacs.

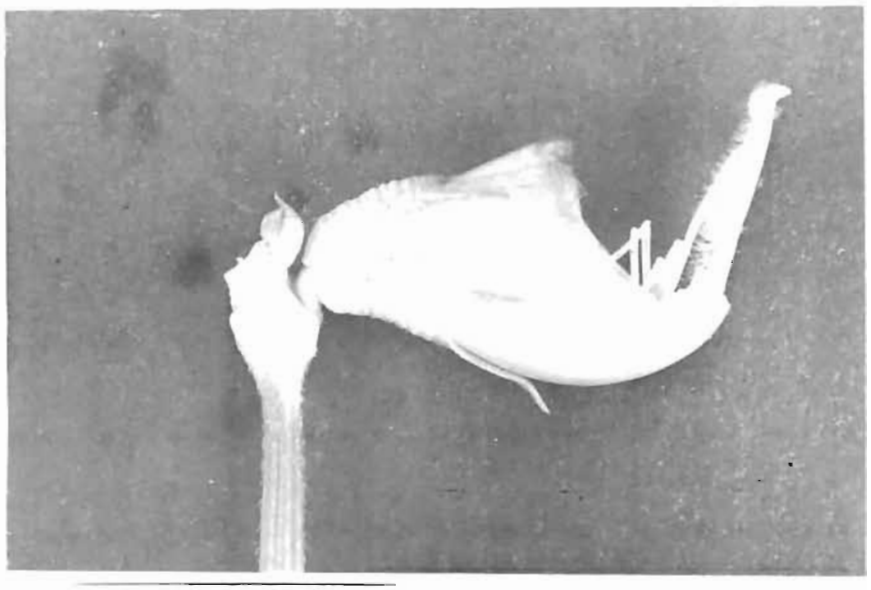


Figure 9.5: Remove other buds on the raceme.

9.11 Pollination.

The emasculated flower is pollinated the following morning if emasculation takes place in the evening. If crossing is done in the greenhouse, collecting freshly opened male flowers is no problem and pollen remains viable for 12-15 hours after anthesis. Pollen to be used from several hours to one or two days later can be viably stored in a plastic bag (refrigerated).

To expose the anther sacs, the innermost petals are removed or slipped downwards and the mass of pollen on the hairy style can be used to pollinate 4 or 5 emasculated buds. Only the obliquely arranged disc-shaped stigma at the tip of the style is receptive (not the hairy portion beneath) (Fig. 9.6).

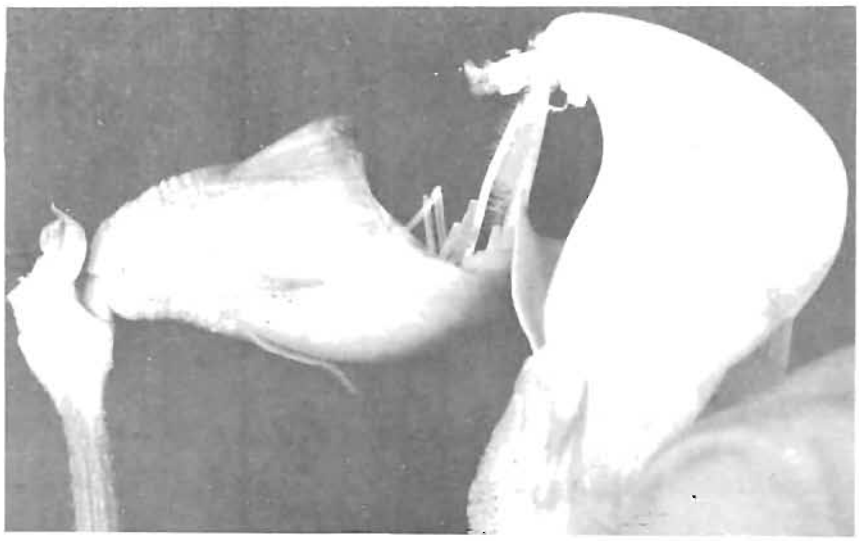


Fig. 9.6: Pollinate the emasculated bud.

A small tag listing the cross and date is affixed to the receme or peduncle beneath the pollinated bud. The crossed flowers are left open and uncovered. To reduce thrips and other insects likely to carry pollen, an insecticide can be applied at regular intervals.

9.12 After pollination.

A good check on the success of a cross can be made three days after anthesis. Moderate temperature and increased humidity appear to increase percentage of fruit setting in hand emasculated crosses. Pods are ready to harvest 18 to 22 days after pollination. Seed losses from pod dehiscence can be avoided by harvesting crosses as soon as the pods begin to dry. Harvested pods should be allowed to dry completely in envelops or paper bags before the seeds are removed.

9.13 Selection:

Selection is one of the oldest procedures used for crop improvement and during this process individual plants or groups of plants are sorted out from mixed populations.

(a) Early methods of selection:

(i) Pure line selection. Single plants are selected from existing variable populations and seed from each plant is sown in progeny rows. Selected lines are then screened in replicated yield trials. Based on their range of adaptation, lines are then considered for release to farmers. This method is simple and is suitable for improvement of unselected local varieties or land races but does not sustain continuous improvement.

(ii) Mass selection. This consists of either the removal of undesirable types from a mixed or variable population followed by harvesting the remaining plants en masse. Seeds are bulked and tested in replicated yield trials. As with the pureline method, mass selection can be successful in the improvement of land races and is also ineffective in producing continuous improvement.

Although substantial improvement in cowpeas can be made simply and quickly by the use of mass and pure line selection within germplasm accessions or land races, there is insufficient opprotunity for genetic recombination and thus there is a limit to improvement because the nearly 100% self-fertilization that takes place in cowpeas prevents natural outcrossing and the gene recombination that would result. Therefore the most widely used methods of handling populations resulting from hybridization are pedigree and bulk method and/or various modifications of these methods.

(b) Pedigree selection.

This involves detailed records of lines of descent of selected individuals in every generation starting with the F_1. Records of performance are also kept. The following is the pedigree selection scheme used in cowpeas.

F_1 generation. A sufficient number of plants is raised either in the greenhouse or field to provide seed to sow F_2 population of a required size. No selection is practiced. Although heterogeneous, all individuals are genetically identical.

F_2 generation. Enough plants per cross are grown to ensure that the population is adequately sampled. Several hundreds or thousands of F_2 plants are often required. The F_2 is the first opportunity for selection and it is ideal to select plants that are homozygous for disease resistance controlled by a single gene. Such elimination reduces the population to a manageable size. At this stage one or two whole crosses may be eliminated if all plants in the population show undesirable characteristics. Selected single plants are harvested individually to produce seeds for the F3 generation.

F_3 generation. Seeds from individual F_2 plants are sown separately in progeny rows of 20-30 plants. Many of these will still be segregating and highly variable but it is possible to identify differences between rows. Artificial infestation with disease and insects should be done whenever possible. Single plants are then selected from the best rows. A few exceptionally good plants are also selected from otherwise poor looking rows. The plants are then harvested separately to produce seeds for F_4 generation.

F_4 generation. Seeds from single F_3 plants are sown as F_4 progeny rows and are handled in the same way as for F3. However, variation within

rows is small due to reduced heterozygosity and more emphasis is placed on selection between rows. Selection is still on a single plant basis but uniform rows may be also harvested in bulk to produce sufficient seed for replicated yield trials.

F5 generation. Seeds from single F4 plants are sown as single row plots but selection is on a row basis. Selection for disease and insect resistance can be carried out. The best rows are then harvested separately and within promising rows that are not, uniform single plants are selected.

F6 to F8 generation. Selected materials are entered in preliminary, advanced and uniform trials at several locations. Information is obtained on different characters including plant type and quality. These trials are continued over more than one season since the performance of cultivars varies from place to place and from year to year. The number of locations and years will depend on climate and other factors. In preliminary yield trials, line characteristics can be observed and yield potential roughly estimated. Lines which meet the selection criteria of plant type, earliness, seed type and yield are then retained and entered in advanced yield trials.

Advantages of Pedigree selection.

(i) performance evaluations in one year,

(ii) rapid elimination of less valuable materials,

(iii) opportunities for inheritance studies with the breeding material.

Disadvantages.

(i) excessive record keeping,

(ii) additional time requirements for handling single plants in the field

(iii) selection is often in one environment.

An example of the pedigree method of selection is presented in Fig. 9.7.

(c) Bulk population breeding.

In this method all the plants from F_2 population are harvested in bulk at maturity without selection. The procedure is repeated in successive generations until reasonable homozygosity has been achieved (F_5 or F_6). After F_5 or F_6 single plants are selected, multiplied and yield tested in the same way as later generations from the pedigree method.

The principal advantages of this method include its simplicity, minimal record keeping and low cost. The chief disadvantage is that natural selection operating in a bulk population may result in the selection of individuals although highly competitive but may be lower yielding or otherwise agronomically undesirable. An example of the bulk population method of selection is given in Fig. 9.8.

The most expensive and time consuming operations in cowpea breeding is yield evaluation. In both pedigree and bulk population methods, considerable time is lost in the process of obtaining homozygosity. To overcome some of the drawbacks of pedigree and bulk methods both single seed descent and early generation yield testing have been attempted and these will be discussed in the following sections.

(d) Single seed descent (SSD) method.

This method consists of harvesting one seed from each F_2 plant in each cross and advancing through each generation to F_5 using one seed per plant in close spacing. Little or no selection is applied until after individual F_4 or F_5 seeds are multiplied to provide enough seed of the corresponding F_5/F_6 progenies to be yield tested.

A Pedigree - bulk selection scheme

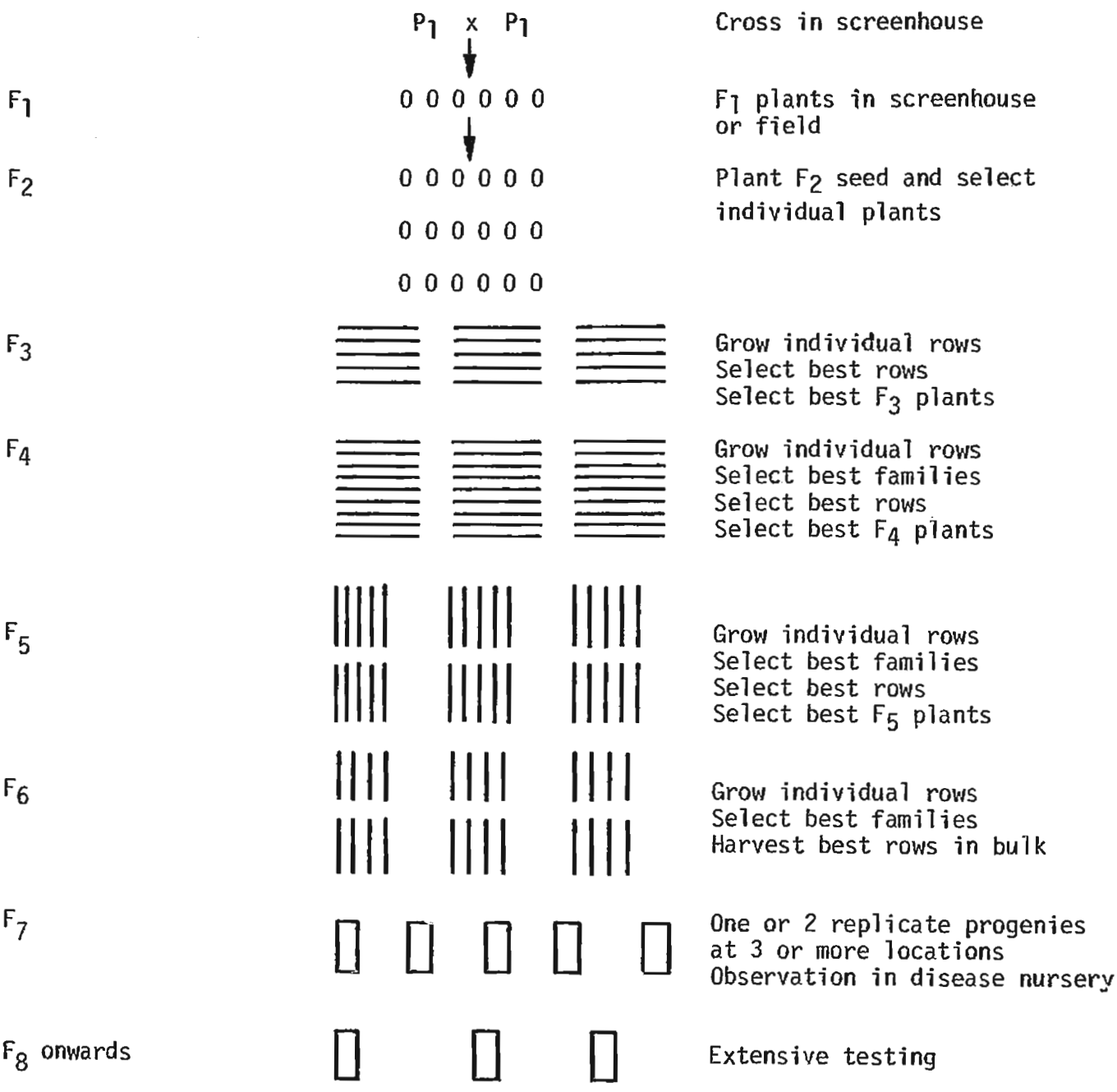


Fig. 9.7: A pedigree-bulk method of selection.

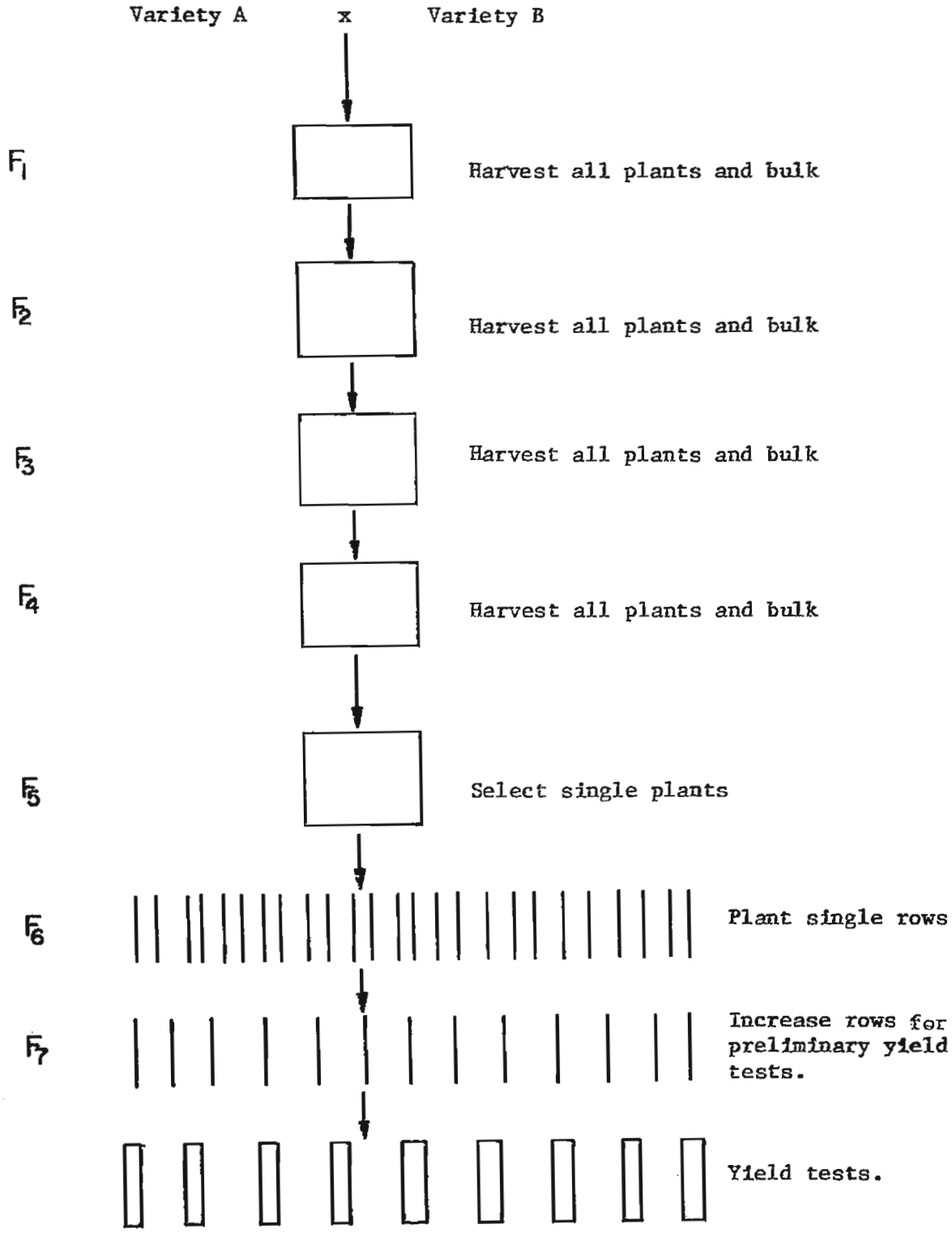


Fig. 9.8: Bulk population method of selection.

Single seed descent is not affected by artificial culture since it does not depend on the reproductive value of the genotypes and the purpose is to advance the generalism as quickly as possible. Often generations are advanced in the greenhouses since only a small population is needed. In cowpeas, 4 generations can be obtained in one year. This in turn reduces cost. When compared with bulk population, SSD is expected to be less laborious for cowpeas and similar crops due to the ease of harvesting one pod with a single seed from each plant. SSD has been found to be equal or better than bulk population or pedigree selection in yielding superior advanced lines. The SSD method, however, has limitations in that it requires yield evaluation on a large number of lines. Another limitation is that there is a danger of plant loss resulting from lack of germination of a single seed or plants failing to set pods. This can be overcome by raising several plants and at harvest taking only one pod. The single seed descent procedure can be illustrated as follows:

Season 1. Grow F_2 plants
Harvest one seed/plant

Season 2. Grow F_3 plants
Harvest one seed/plant

Season 3. Grow F_4 plants
Harvest one seed/plant

Season 4. Grow F_5 plants
Harvest individual plants

Season 5. Grow individual rows from each individual plant
Harvest selected rows in bulk

Season 6 onward: Extensive testing of F_5 derived lines.

(e) Early generation yield testing.

A major problem in pedigree selection is the identification of superior F_2 plants. Since it is generally accepted that selection for yield on a single plant basis is ineffective, the breeder attempts to identify the superior F_2 by assessing their progenies on a line basis in F_3. The usual procedure, because of limited amount of seed available from single plants, is to evaluate yield potential under one environment and assessing the selected lines for wide adaptability in later generations. If F_3 can be grown at a number of well chosen locations, selections could be made of lines that give the highest average yields. Thus, if the breeder is able to identify a few promising materials at an early stage, he concentrates his efforts on fewer materials which reduces costs. Early generation testing can take the following forms:

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1. Grow F_2 plants
   Harvest each F_2 plant individually.

2. Grow individual rows
   Select best rows
   Harvest F_4 seed of selected rows - bulk.

3. Grow replicated yield tests with F_4 seed
   Select highest yielding lines.

4. Grow F_5 plants from selected lines
   Harvest selected F_5 plants individually

5. Grow individual rows
   Harvest selected rows in bulk

6. Extensive testing.

(f) Back cross method.

This is a form of recurrent hybridization by which a superior character

is added to an otherwise desirable variety. The latter to which the superior character is being added enters into each backcross and is known as the recurrent parent. The donor parent for the superior character does not enter into the backcrosses and is known as the non-recurrent parent.

The purpose of the backcross is to recover the genotype of the recurrent parent aspect for the addition of genes of the superior character which is being contributed from the non-recurrent parent.

The number of back crosses may vary from one to eight depending on how the breeder wishes to recover the genes from the recurrent parent. The back cross procedure is most easily carried out if the character being transferred is simply inherited, dominant and easily recognised in the hybrid plants. Recessive characters are more difficult to introduce.

This procedure is used at IITA to modify the seed type and introduce resistance to new diseases into improved cultivars. At IITA, the VITA lines have medium to high yields but have small seed. In Northern Nigeria, cowpeas are accepted only with large, white rough testa seed types. To correct this, some sources of large seeds are crossed with those that have small seeds and the F_1's of these crosses are respectively crossed back to the recurrent parents. The back cross progeny are then selected for large seed size. The following scheme (Fig. 9.9) is an illustration of the back cross method involving transfer of disease resistance into susceptible but good yielding variety.

The advantage of this scheme is that high levels of homozygosity can be obtained in a very short time.

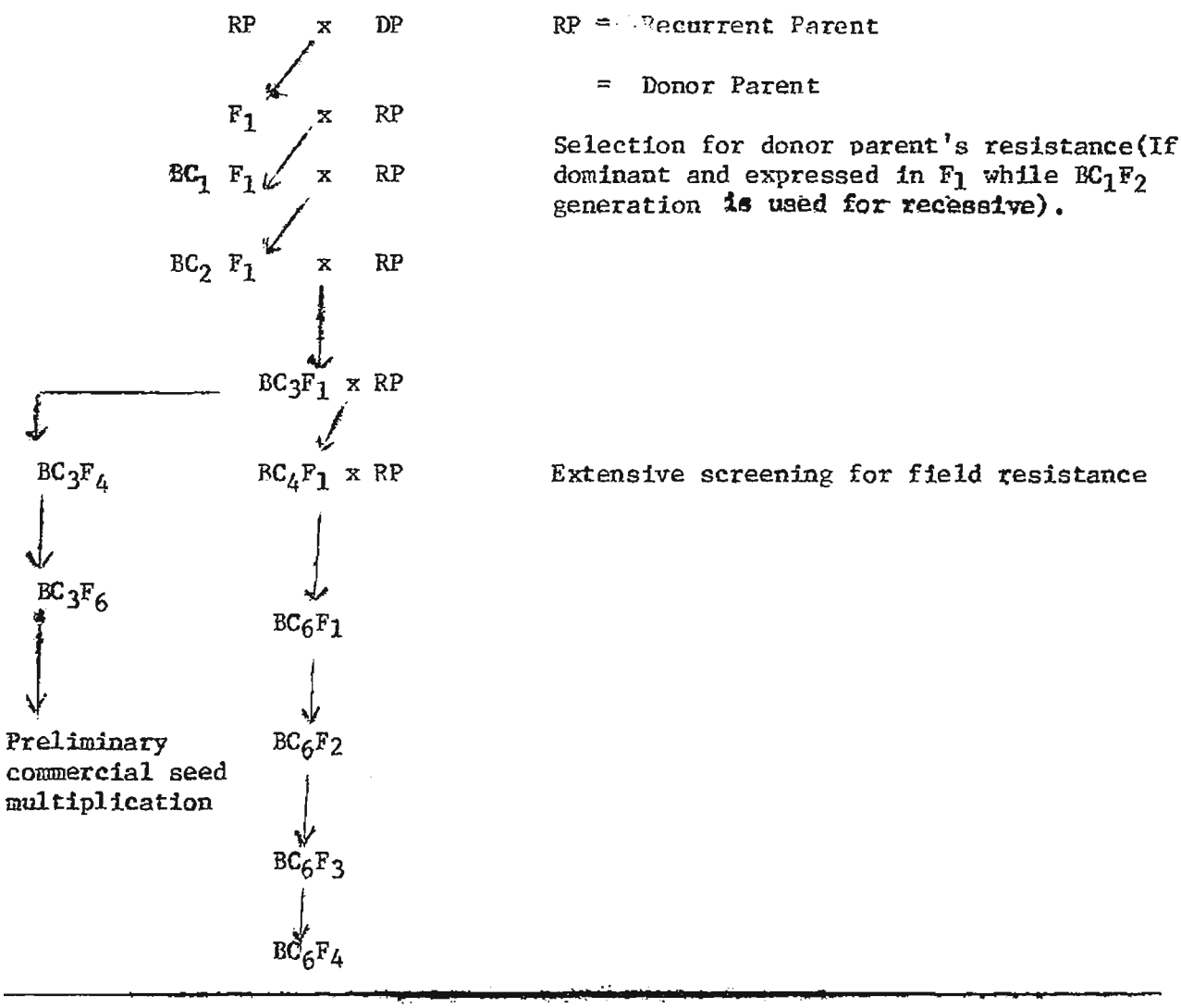

Fig. 9.9: A backcross Scheme.

9.14 Recent advances in breeding methodology.

In recent years, traditional methods of breeding have been considerably modified to maximize variation and to increase the rate of genetic improvement. Thus, emphasis has been placed on the development of recurrent selection schemes with more than one generation in an annual cycle and repeated inputs of diverse material.

Cowpea is especially suitable for manipulation in these ways because of the short period of time from sowing to maturity which enables the breeder to grow up to 4 generations in a year, and the ease of crossing. A major step forward in cowpea breeding has been the identification of stable sources of male sterility. This condition is controlled by a single recessive gene which results in disturbances at meiosis so that the pollen is infertile and unable to effect fertilization. Thus, it is possible for the breeder to greatly increase the number of crosses he makes since nature does the equivalent of emasculation and may even do the pollination, too, with the help of insects. Through such a scheme it is possible to develop large numbers of new gene combinations which cannot be easily produced by other ways. Emasculation and chances of incidental selfing are eliminated. This has enabled population improvement - a form of recurrent selection to be used with cowpea which is a self-pollinated crop.

9.15 Improvement via integrated disciplinary approach.

A viable breeding program relies on other disciplines. A plant breeder has to keep in touch with the current researchers in other allied subjects since it helps him to define his short and long term objectives.

With the help of entomologists and pathologists lines have resistance or tolerance to pests and diseases can be identified. A combination of this genetic resistance in the plant with minimum application of chemicals provides a low cost input system of management that can be adopted by farmers. Physiologists can identify genotypes that give good yields despite environmental and physiological stress. Agronomists can assist in evaluating lines under various systems of crop management. The Microbiologist assists in selecting specific crop genotypesand Rhizobia strain with a view to maximize biological nitrogen fixation. A variety which is excellent in yield but unacceptable to the consumer is of limited value. Biochemists and food Technologists can assess the nutritional value and functional properties to ensure that these characters are maintained or improved in new cultivars. The plant breeder, therefore, has the task to combine through genetic manipulation these selected characters of pest and disease resistance, physiological factors, that maximize yield and a positive response to good management production and quality.

9.16 Yield testing.

The most expensive and time consuming operation in cowpea breeding is yield evaluation. The yield of new pure lines must be compared with existing cultivars to identify those that are superior. In establishing a yield test, the breeder must decide which lines will be compared. When a breeder has many lines he cannot handle them together in one set.

The lines are generally grouped into sets of 20 or more enteries with common checks. Lines similar in maturity frequently are put in the same set.

Each set of materials is planted at 2 or more locations using 2 or more replications. Thus the first stage of preliminary testing is carried out directly in the breeding nursery on elite homozygous or advanced generations (F_6 and beyond) following single plant selection harvest. About 10-20% of these advanced lines are harvested. These yield results together with visual evaluations, disease ratings and other agronomic characters are used as a basis for selecting lines for preliminary testing. Plots in preliminary trials usually consist of 2-4 rows, 3-5m in length and 0.75m apart, may be replicated 2-4 times and are conducted in both rainfed seasons.

From the best performers in preliminary trials and sometimes include a limited number of exceptional lines from the breeding nursery. Advanced trials normally consist of 4-6 rows, 4m long with plots replicated four times and are grown in both rainfed seasons.

The best performing lines from the previous trial and advanced testing are included in uniform trials and offered to interested cooperators. Thus any genetic material distributed from IITA is automatically released to cooperators and the host country whenever it proves useful. Presently greater emphasis is given to strong national and regional programmes (e.g. UpperVolta, Tanzania, Brazil). A schematic presentation of a cowpea breeding programme is presented in Fig.9.9.

9.17 Achievements made at IITA in cowpea breeding.

Selection based on the evaluation of early and advanced breeding generations at locations that represent principal ecological zones has contributed significantly to the progress made in the development of better varieties of cowpeas.

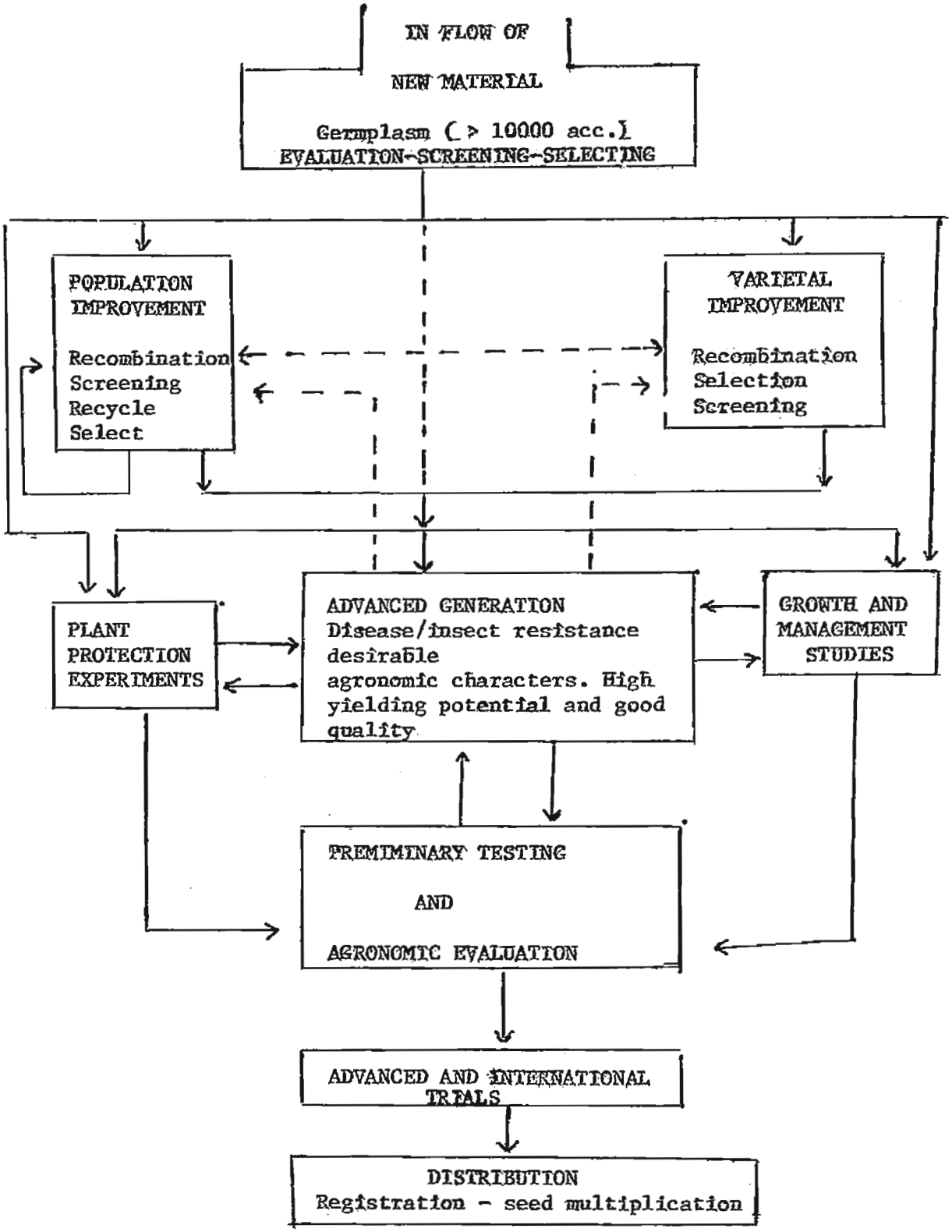

Fig.4.10: Basic scheme for cowpea improvement.

The idenfication of host plant resistance to most of the major diseases and inoculation of breeding nurseries to create field epidemics have led to the development of many improved lines with high levels of disease resistance. Some of the important sources of multiple and specific resistance are presented in Tables 9.1 and 9.2. The pedigrees of some of these lines are presented in Table 9.3. Progress has also been made in the identification of lines resistant to particular insect pests of cowpea. Some of these lines are shown in Table 9.4. One notable example is Tvx 3236 which yields reasonably well with only two chemical sprays (Table 9.5)

Table 9.1: Sources of resistance to different diseases in cowpea.

Disease	Resistant sources
Anthracnose, Rust Cercospora, Bacterial pustule, CYMV	TVu 310, 345, 347, 410, 645, VITA-1, VITA-3
CYMV, Cowpea Mottle, CAMV Southern Bean Mosaic, Golden Mosaic.	TVu 393, 493, 1185, 2755
Fusarium wilt (Furasirum oxysporum)	TVu 109-2, 347, 984, 1000
Bacterial blight (Xanthomonas vignicola)	TVu 347, 410, 483-2, VITA-3, VITA-4
Scab (Sphaceloma sp.)	TVu 853, 1404, 1433, VITA-4
Septoria (Septoria vignae)	TVu 456, 483-2, 486, 1433, VITA-4
Brown Blotch (Colletrotrichum capsici)	VITA-1, VITA-4
Root Knot (Meloidogyne incognita)	VITA-1, VITA-4
Pyytophthora Stem Rot (Phytophthora vignae)	Ku 235

Table 9.2: High yielding advanced breeding lines of cowpea with multiple disease resistance

Breeding line	Mean Disease Score*							
	BP	BB	Anth.	CAMV	CYMV	B. Blotch	Septoria	WB
TVx 1850-01E	1	1	1	1	1	1	1	2
TVx 4033-1	1	1	1	1	2	1	2	1
TVx 4659-02E	1	1	1	1	1	2	1	2
TVx 4662-024E	1	2	1	1	2	1	1	1
TVx 5802-1	1	1	1	1	2	1	1	1
TVx 5804-1	1	1	2	1	1	1	1	1
TVx 5822-1	1	1	2	1	1	1	2.5	1
Ife Brown	1	1	5	3	3	3	4	2
Most Susceptible Lines	4.5	3	5	5	5	4	5	4

*1 = Disease free 5 = Severe symptoms

BP = Bacetrial pustule; FB = Bacterial blight; Anth = Anthracnose,

CAMV = Cowpea aphid borne mosaic; CYMV = Cowpea yellow mosaic

B.Blotch= Brown blotch; WB = Web blight

Table 9.3; Pedigree of advanced breeding lines of cowpea with multiple disease resistance.

Breeding line	Pedigree
TVx 1850-01E	VITA-1 x (TVu 37 x TVu 530)
TVx 4033-1	(TVu 76 x VITA-3) x TVu x TVu 2027
TVx 4659-02E	TVx 1850-o1E x (TVu 76 x VITA-3) x TVu 1485
TVx 4662-013E	TVx 1850-01E x (TVu 3563 x VITA-1)
TVx 4662-024E	TVx 1850-01E x (TVu 3563 x VITA-1)
TVx 5802-1	[(TVu 625 x (TVu 317 x (TVu 530 x TVu 193)) xTVu8445
TVx 5802-4	{TVu 4200 x (TVu 317 x (TVu 530 x TVu 193))x TVu8445
TVx 5822-1	[(TVu 37 x TVu 530) x (TVu 115 x TVu 1038)] xTVu4573

Table 9.4: Sources of resistance to different insect pests of cowpea.

Insect pest	Sources of resistance
Leafhopper	TVu 59, 123, 662
Aphids	TVu 36, 62, 801, 3000
Thrips	TVu 1509, TVu 2870
Maruca	TVu 946
Bruchid	TVu 2027

Table 9.5: Performance of TVx 3236 with minimum insecticide protection.

Variety	Yield kg/ha Insecticide Application*	
	2	4
TVx 3236 (Resistant)	1500	1589
Ife Brown (Susceptible)	956	1667

2 = Sprayed at 35 and 60 DAP

4 = Sprayed at 30, 40, 50, 60 DAP

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CHAPTER TEN

INSECT PESTS AND THEIR CONTROL

10.1 Introduction.

Insect pests cause serious yield losses by attacking seedlings, growing plants and stored grain. Roots, leaves, ovules and seeds in pods and in storage are all affected. In addition to causing direct damage, insects are important vectors of virus diseases. The damage they cause also opens the way for attacks by fungi and bacteria. Insects are well adapted to causing damage because of their small size resulting in low food requirements and the ability to avoid predators and extremes of weather, and their rapid reproductive rate; pathogenetically as well as sexually, by which they can take advantage of brief opportunities which arise for them to increase. Some insects have the ability to hibernate until favourable conditions arise. Insects also have the advantage of mobility in seeking food, shelter and favourable breeding grounds and a wide adaptability to different environments. Their superior body structure results in the efficient conservation of water and nutrients, and combines strength with lightness.

A wide range of insects attack cowpeas at all stages of growth and in storage and a comprehensive list of cowpea pests has been given by Singh and Allen, (1980). A Handbook on cowpea pests and diseases has been published for research and extension workers (Singh and Allen, 1979).

10.2 General classification.

We all know insects. The commonest ones are mosquitoes, flies, cockroaches, termites and grasshoppers. All insects belong to the Phylum Arthropoda

and Class Insecta.

The animal kingdom is divided into major groups called *Phyla* (sigular, Phylum). Each phylum has a name and its members have certain common structural characters. Some of the principal phyla of the animal kingdom are:

Protozoa - single-celled animals

Porifera - sponges

Coelenterate - jelly fish, corals

Platyhelminthes - tapeworms, flukes, flatworms

Nemathelminthes - roundworms, nematodes

Mollusca - snails

Echinodermata - starfish

Annelida - earthworms, leeches

Arthropoda - millipedes, shrimp, spiders, insects

Chordata - fish, amphibians, reptiles, birds, mammals.

Each phylum is further sub-divided into <u>classes</u> (singular <u>class</u>) based on their structural characters. Each class has a name and certain structural characters in common. Some of the classes of the phylum *Arthropoda* for instance, which students in agriculture may come across are:

Crustacea - crustaceans: crabs, shrimps

Diplopoda - millipedes

Chilopoda- centipedes

Insecta - insects

Arachnida - spiders, mites, ticks, scorpions etc.

The insects belonging to class Insecta are characterized by having three body segments - heads, thorax, and abdomen, one pair of artennae, three pairs of legs and usually one or two pairs of wings.

The class Insecta is further sub-divided into orders, the orders into families, the families into genera (singular, genus) and genera into species. The basic category in the scheme of classification is species. A species is fundamentally similar in structure, capable of interbreeding and producing fertile offspring. A species is referred to by a scientific name. The scientific name of a species consists of the genus and species name. Scientific names are always printed in italics; if written or typewritten, they are always underlined: example : *Maruca testulalis**. Some insects which are more common, also have a common name. Pod borer is the common name for *Maruca testulalis*. Some of the economically important orders under the class Insecta are:

Orthoptera - grasshoppers

Isoptera - termites

Thysanoptera - thrips

Hemiptera - bugs

Homoptera - leafhoppers, aphids, whiteflies

Coleoptera - beetles

Lepidoptera - butterflies, moths

Diptera - true flies

Hymenoptera - ants, bees, wasps

No attempt is being made to mention the families under each order. Interested students should refer to taxonomy textbooks.

*Note Genus begins with a capital letter, species with a small letter.

10.3 Classification of insect pests

1. Common name - Leafhoppers

Homoptera

Jassidae

Empoasca dolichi Paoli

2. Common name - Foliage thrips

Thysanoptera

Thripidae

Sericothrips occipitalis Food

3. Common name - Striped foliage beetle

Coleoptera

Chrysomelidae

Paraluperodes quaternus (Fairmaire) = (*Luperodes lineata* Kars)

4. Common name - Foliage beetle

Coleoptera

Chrysomelidae

Ootheca mutabilis Sahlb.

5. Common name - Aphid

Homoptera

Aphididae

Aphis craccivora Koch

6. Common name - Flower thrips

Thysanoptera

Thripidae

Taeniothrips ajostedti (Tryb.)

7. Common name - Flower and pod borer

Lepidoptera

Pyralidae

Mauraca testulalis Gey

8,9, & 10. Common name - Pod sucking bug

Hemiptera

Coreidae

Acanthomya horrida Germ.

Anoplocnemis curvipes F.

Alydidae

Riptortus dentipes F.

11. Common name - Pod borer

Lepidoptera

Olethrentidae

Cydia ptychora =(*Laspeyresia ptychora* Meyr).

12. Common name - Cowpea storage weevil

Coleoptera

Bruchidae

Callosobruchus maculatus (F)

Other insect pests that are occasionally encountered are:

1. Hemiptera

Pentatomidae

Nezara viridula

2. Coleoptera
Lagriidae
Lagria villosa

3. Coleoptera
Lagriidae
Chrysolagria nairobana

4. Coleoptera
Curculionidae
Apion varium

5. Coleoptera
Curulionidae
Nematocerus acerbus

6. Coleoptera
Galerucidae
Barombia humeralis

7. Orthoptera
Pygomorphidae
Zonocerus variegatus

8. Lepidoptera
Lycaenidae
Euchrysops malathana

(9) Lepidoptera
Lycaenidae
Virachola antalus

(10) Lepidoptera
Noctuidae
Spodoptera littoralis = (*Prodenia litura*)

(11) Lepidoptera
Pyralidadae
Eldana saccharina

(12) Coleoptera
Meloidae
Mylabris farquharsoni

10.4 Insect control.

Many people think entomology means insect control. Actually the meaning of entomology is the study of all aspects of insects. Nevertheless,insect control is probably the most important aspect of entomology. Insect control is adopted to minimise or eliminate competition for food and space. Insects are also carriers of several dreadful diseases.

Insect control classically is best obtained by chemical control. There are several other methods that may reduce the pest infestation and are either replacement for chemical control in certain environments,or add a supplement to chemical control. Insect control can be divided into seven broad categories:

1. Chemical control
2. Host plant resistance
3. Biological control
4. Cultural control
5. Physical or mechanical control
6. Integrated control
7. Legislative control

10.4.1 Chemical control:

This is probably the most expensive but also the most effective control method. Handling of insecticides can also be dangerous. Chemical control is based on the use of insecticides that kill the insect with their chemical action. Insecticides are classified according to their mode of action into four categories:

Stomach

Contact

Systemic

Fumigant

Insecticides, when applied, can kill an insect by contact (nervous system) or when the sprayed portion is eaten by the insect as stomach poison or due to both. Systemic insecticides when sprayed on the plant are absorbed by the plant tissue and translocated to the other parts of the plant. Fumigants affect the respiratory system. Insecticides are classified into four categories according to their structure:

Chlorinated hydrocarbons - BHC, DDT, Dieldrin, Aldrin

Organophosphorus - Parathion, Malathion

Carbamates - Carbaryl

Chlorphinamidine - Galecron.

10.4.2 Host plant resistance:

In recent years this method of control has received a great deal of attention. It involves breeding of crop varieties resistant to pest attack. It is the most economically important and environmentally sound method of pest control. Insect resistance is a "relative" phenomenon. It is defined as the relative amount of heritable qualities possessed by the plant that influence the ultimate degree of damage done by the insect. In practical agriculture it represents the ability of a certain variety to produce a larger and better-quality crop than ordinary varieties at the same level of insect populations (Painter, 1951). The word "relative" is important in this definition because

host plant varieties immune to insect attack have seldom been recorded, and even highly resistant varieties suffer some damage under heavy infestation (Pathak, 1972).

The nature of varietal resistance to insect pest has been classified into three broad categories: non-preference, antibiosis and tolerance. A plant is non-preferred when it possesses factors that render it unattractive to insect pests for their oviposition, feeding, or shelter. It has antibiosis when it adversely affects the insects feeding on it. The plant is tolerant if, despite supporting a population large enough to severely damage susceptible hosts, it suffers little damage (Painter, 1951). Table 10.1 shows some IITA cowpea cultivars that have resistance to some insect pests.

10.4.3 Biological control.

This is defined as the action of parasites, predators and pathogens in keeping the pest population under control. Several parasites and predators are present in nature, and indiscriminate use of insecticides can upset their balance. Therefore, for biological agents to play their maximum role, insecticides must be applied carefully and only when necessary.

10.4.4 Cultural control.

This method requires certain cultural practices that may allow the crop to escape the pest damage. Such practices could involve planting a crop when the peak activity of the pest is not present, for example keeping the fields free from weeds to avoid pest infestation. Certain crop mixtures (e.g., mixed cropping) also have been found to reduce pest incidence. In order to escape pest damage, short-duration varieties are also planted.

Table 10.1: Cowpea cultivars identified as resistant to insect pests, IITA.

Pest	Cultivars
Empoasca dolichi (damage to foliage)	TVu 59, TVu 123, TVu 662 and VITA-2 - Resistant
	VITA-1, VITA-5 and TVx 4-5C - Moderately resistant
Maruca testulalis (damage to stem)	TVu 946, TVu 3962 and VITA-5 Resistant
	VITA-4 - Moderately resistant
Taeniothrips sjostedti (damage to flower buds)	TVu 1509, TVu 7279 and TVu 946 Moderately resistant
	VITA-4 and VITA-5 - Less susceptible
Acanthomyia horrida (damage to pods)	VITA-4 and TVu 7279 - Moderately resistant
Cydia ptychora (damage to pods)	TVu 946, TVu 3799 and TVu 4579
	- Moderately resistant
Callosobruchus maculatus (damage to seed)	TVu 2027 - Resistant
Aphis craccivora (damage to plant)	TVu 408P_2, TVu 410, TVu 2740, TVu 3417 and TVu 3509 - Resistant

10.4.5 Physical control.

This is a simpler method of pest control that may be effective with only a few insect species. It involves physical destruction of the pests. For example cowpea foliage beetle, *Ootheca mutabilis*, adults and eggs found in the soil could be destroyed by plowing the land. Sometimes initial populations of cutworms, *Spodoptera littoralis* can be checked by collecting the larvae by hand.

10.4.6 Integrated control.

This method, defined as an integrated pest management system, is an interdisciplinary approach and economic method of pest control. It utilizes insecticidal, biological, cultural and physical control and the most important component insect resistant varieties.

10.4.7 Legislative control.

This is essentially quarantine activity. Infestation by stored grain pests can be introduced if new material is not properly checked. Movement of seed material should therefore be carefully checked.

10.5 Insecticide formulations.

Insecticides for pest control have to be appropriately formulated for storage, handling and application. The common types of insecticide formulations are mentioned here.

(i) Dusts (D)

These are ready-made mixtures for dusting on the plants. The toxicant is diluted with talc, sulfur, walnut shell etc. These are sold as 5 or 10% dust and applied by a duster.

(ii) Wettable powder (WP).

The toxicants are absorbed or adsorbed on powders that can be readily mixed with water due to a wetting agent and form suspension in water. The sprayers have to be constantly agitated to give uniform coverage of insecticide.

(iii) Emulsifiable concentrate (EC)

These are made by dissolving the toxicant and an emulsifiable agent in an organic solvent. These are diluted in water and sprayed. Most insecticide formulations are available in this form.

(iv) Solution concentrate (SC):

These are molecular mixtures of the toxicant with a solvent that can be dissolved directly in the water.

(v) Insecticide granules (G)

These are similar to dusts but are coarser formulations for application in the soil. The toxicant activity is systemic, i.e. absorbed through the roots and translocated to other parts of the plant.

(vi) Ultra Low Volume (ULV):

These are comparatively newer formulations for direct application. A special type of insecticide sprayer is used and is mostly battery-operated for ground application. It is getting more popular for aerial application.

(vii) Aerosols

These are air suspensions of solid or liquid particles of ultra-microscopic size that remain suspended for long periods. Fogging of insecticides creates aerosols.

(viii) Baits. It consists of a toxicant or poison mixed with an attractive substance.

10.6 Insecticide calculations.

Except dusts, granules and ULV formulations, insecticides need to be diluted in water. The volume of spray applied per unit area varies according to the type of crop, the nature of the spray equipment and the size of spray particles required. Based on this, there are three categories:

Ultra low volume (ULV) - 1 to 2 litres per hectare

Low volume (LV) - About 100 litres per hectare

High volume (HV) - 300 to 1000 litres per hectare.

10.6.1 Dosage calculation:

Normally insecticide application is mentioned as toxicant active ingredient (a.i.) in grams per hectare. The amount of water required is based on LV or HV application. It is necessary to know:

1 hectare (ha) = 10,000 square meters (m^2)

1 kilogram (kg)= 1000 grams (gr)

1 litre (L) = 1000 millilitre (ml)

Toxicant active ingredient = a.i

Plot size is measured in m^2

Insecticide dosage is measured as gr. a.i.

Water is measured as L/ha

Example 1: For an insecticide formulation 20 EC, calculate amount of water and insecticide required for spraying 100 m^2. Dosage per hectare is 500 gr. a.i. in 1000 litres of water per ha.

First calculate insecticide a.i. for 100 m^2.

$$= \frac{500 \times 100}{10,000} = 5 \text{ gr. a.i.}$$

Therefore amount of insecticide required for 100 m^2

$$= \frac{100 \times 5}{20} = 25 \text{ ml.}$$

Amount of water required for 100 m^2

$$= \frac{1000 \times 100}{10,000} = 10 \text{ litres}$$

Answer = 25 ml. of insecticide in 10 litres of water.

For bio-assay or even for normal spraying, sometimes the spray solution is expressed as a.i. percentage. How to calculate the amount of insecticide and water is explained below.

Example 2:

For an insecticide formulation 20 EC, calculate amount of insecticide and water required to make 1.0, 0.5, 0.1, 0.05% solution.

For 1.0% solution: 1.0% solution means - 1 part (ml) of a.i. of insecticide in 100 parts (ml) of water.

Since the insecticide formulation is 20 EC - it means to get 1 part (ml) a.i. of insecticide, we have to add 5 parts (ml) of insecticide formulation.

Formulation calculation $= \frac{100}{20} = 5$

Therefore 1.0% solution is obtained by mixing 5.0 ml of insecticide formulation in 100 ml. of water.

For 0.5% solution: For 1.0% solution, insecticide required = 5.0 ml.

Therefore for 0.5% solution insecticide required = 0.5 x 5.0

= 2.5 ml in 100 ml. of water.

For 0.1% solution: It will be 0.1 x 5.0 = 0.5 ml.

For 0.05% solution: It will be 0.05 x 5.0 = 0.25 ml.

For calculating the dosage per litre, multiply the dosage for 100 ml x 10. Normal recommended dosage for control of grain legume pests is 400 to 600 grams a.i. per hectare for most insecticides. For Gammalin a higher dosage of 1000 grams a.i. per hectare is recommended. Amount of water per application is 100 litres for LV spray and 400 to 800 litres for HV spray. Table 10.2 shows the insecticides available on the market while Table 10.3 gives the mode of action and LD_{50} values for some insecticides that are available on the market.

Table 10.2: Insecticides: Common and Trade Names.

Common Name:	Trade Name:	Manufacturer
Surecide	Surecide	Sumithion Co.
Chlorpyrifos	Dursban	Dow Chemical Co.
Monocrotophos	Azodrin	Shell Co.
Monocrotophos	Nuvacron	CIBA-GEIGY
Methomyl	Lannate	Du Pont
Entrimfos		Sandoz
Lindane	Gammalin	Shell
DDT	DDT	ICI
Endosulfan	Thiodan	Hoechst
Dimethoate	Rogor	Bayer
Diazinon	Diazinon	CIBA-GEIGY
Imidan	Imidan	Stanffer Ch. Co.
Chlordimeform	Galecron	CIBA-GEIGY
Phosphamidon	Dimecron	CIBA-GEIGY
Dichlorvos	DDVP	CIBA-GEIGY
Carbaryl	Sevin	Union Carbide
Fanthion	Lebaycid	Bayer
Temophos	Abate	American Cyanamid
Tetrachlorvinphos	Gardona	Shell
Carbofuran	Furadan	FMC
Fenitrothion	Sumithion	Sumithion
Fenitrothion	Agrothion	ICI
Methidathion	Supracide	CIBA-GEIGY
Bacillus thuringiensis	Thuricide	Sandoz

Table 10.3: Mode of action and LD_{50} Values*

Trade Name	Acute oral LD_{50} mg/kg	Acute dermal LD_{50} mg/kg	Mode of Action
Furadan	11	10,500	Systemic
Lannate	17	5,000	Systemic, contact
Dimecron	20	125	Systemic
Azodrin	20	342	Systemic
Nuvacron	20	342	Systemic
Thiodan	30	110	Stomach, contact
Surecide	44	72	Stomach, contact
DDVP	56	107	Contact, stomach Fumigant
Supracide	65	120	Contact, stomach
Gammalin	88	1,000	Stomach, contact
DDT	113	350	Stomach, contact
Galecron	127	3,000	Systemic
Dursban	163	1,000	Contact, stomach
Imidan	300	1,000	Stomach, contact
Lebaycid	250	330	Contact, stomach
Diazinon	300	800	Contact, systemic
Rogor	320	650	Systemic, contact
Sevin	500	850	Contact, stomach
Sumithion	500	1,300	Contact
Agrothion	500	1,300	Contact
Gardona	4, 000	5,000	Selective
Abate	8, 600	4,000	Contact
Thuricide	Harmless to human		Selective

* Test animal - rat,.

10.7 Pests of cowpeas

Many insect pests attack all parts of cowpea plants at every stage of cowpea plants at every stage of growth (Figure 10.1) as well as in storage. The most important pests are leafhoppers, aphids, beetles which feed on foliage and flowers, flower thrips, lepidopterous pod-bores, bugs which suck pods, and the storage weevil (Singh and Allen, 1980).

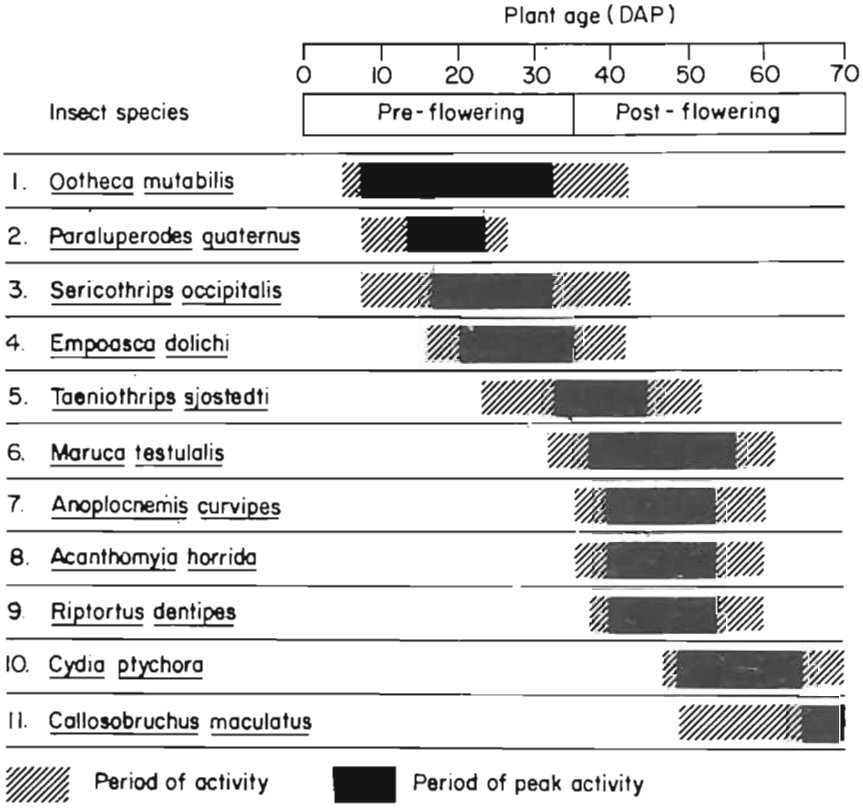

Fig. 10.1: Diagrammatic presentation of cowpea insect pest complex, time of occurrence and peak activity on prima cowpea.

10.7.1 Leafhoppers:

Empoasca dolichi Paoli has been reported as a minor pest of cowpea during the seedling stage (Taylor, 1964). Recent observations indicate that large numbers are found on the August-September planted crops causing serious damage to certain cowpea varieties.

The leafhoppers are greenish and are found feeding on the underside of the leaf. The characteristic damage symptom is leaf cupping or curling, later the leaves dry and fall off. Infested plants loose plant vigor and severely infested plants dry up at the seedling stage.

Adult leafhoppers lay eggs in the veins on the underside of the leaf. Nymphs feed on the leaves after emergence. The life cycle takes about 20 days. Leafhopper damage is determined by visual rating of foliage (1 to 5 score) at 25 to 30 days after planting (DAP). (1 = 0 to 1% damage, 2 = 2 to 5%, 3 =6 to 25%, 4= 26 to 50%, 5 = 51 to 100%). Insect count is taken by sweeping with insect nets or sucking leafhoppers per plant by a D-Vac at 25 to 30 DAP during cooler hours of the days. Nymphal count on the underside of leaf is also a good measure.

Several insecticides, Azodrin, Thiodan, DDT, Dursban, Sumithion, Rogor, Surecide, Lannate and Dimecron, have been found effective against this pest. Normally one insecticide application at 20 DAP is sufficient to control this pest. Furadan, Thimet and Miral granules applied in the soil at 1.0 kg a.i./ha applied at the time of planting were also effective. Recently at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, several leafhopper-resistant cowpea varieties were identified. Some of them are:

TVu 59, TVu 123, TVu 662, VITA-1, VITA-3, VITA-5 and TVx 4-5c. These varieties do not need insecticide protection against leafhoppers. It has been observed with several varieties that plants which suffered from leafhopper damage in the pre-flowering stage and appeared defoliated, improved dramatically in the post-flowering stage, later appearing normal. The only effect of leafhopper infestation on these varieties was that flowering was delayed by 5 to 7 days. This indicates that cowpea plants have a good compensatory mechanism for loss of vigor.

10.7.2 Foliage thrips.

Sericothrips occipitalis Hood. is described mainly as a leaf-feeder and a serious pest of cowpea only under greenhouse conditions (Taylor , 1969). Observations made at IITA confirmed that it is a serious pest in warm greenhouses especially under drought stress conditions. It was further observed that it is a pest on cowpea seedlings in the field on off-season crops grown under irrigation.

The foliage thrips are tiny brownish insects found mostly on the underside of the leaves and on foliage buds. The characteristic feeding symptoms are interveinal necrosis and deformed leaves. Infested plants are stunted and die prematurely under severe infestation. The adult thrips are protected on the underside of the leaf in the curled areas formed by the feeding of leafhoppers and foliage thrips. A heavy rain usually reduces the pest population drastically. This may be one reason why it has not been observed as a pest on the crop grown in the main season. The biology of this pest is not fully known. It appears that the eggs are laid in foliage buds, Nymphs feed on the

foliage buds and on young leaves. The thrips population is recorded by tapping the plants at 20 DAP over a hard white board and counting the total number of thrips. A visual damage rating of foliage (1 to 5 score) similar to leafhopper visual score has been used. Several insecticides, Furadan, Azodrin, Dursban, Surecide, Abate and Lebaycid have been found effective and one single application at 20 DAP was found adequate. Furadan, Thimet and Miral granules applied in the soil at planting time at 1.0 kg a.i./ha were also found effective.

10.7.3 Striped foliage beetle.

Paraluperodes quaternus (Fairmaire), (*Luperodes lineata*) is a small (about 4-mm long) striped beetle with white and light brown longitudinal markings. The adults attack young cowpea seedlings by feeding on newly emerged leaves, mostly at the margins of the leaves. The biology of this pest is not fully known. Adults lay eggs in the soil, the larvae and pupae are found in the soil. After emergence, adults feed on the leaves, and is an important vector of cowpea mosaic virus (CPMV) Whitney and Gilmer (1974). It is very difficult to count the adult population as the beetles are easily disturbed and fall on the ground. A visual damage score of 1 to 5 based on adult feeding on foliage has been used at IITA. (1 = 0 to 5% feeding damage, 2 = 6 to 10%, 3 = 11 to 25%, 4 = 26 to 50%, 5 = 51 to 100%).

Rarely have large numbers been noticed on the field necessitating insecticide application. Certain insecticides including BHC, Thiodan and Rogor have been found effective.

10.7.4 Foliage beetle

Ootheca mutabilis Sahl. is one of the most important foliage-feeding beetles that infest cowpea seedlings. The beetles feed on the leaves' chlorophyll, leaving leaf veins that later result in feeding holes. Whenever there are many, cowpea seedlings are completely defoliated resulting in death of the plants. It is the most important vector of CPMV and is largely responsible for the transmission of this virus (Taylor, 1964).

The beetle is about 6-mm long, oval and light brown. Sometimes, however, few dark brown or even black beetles are found. The adults lay eggs in the soil; larvae feed on the plant roots and pupate in the soil. Adults emerge immediately after rains. The biology of this pest has been studied in detail by Ochieng (unpublished). The method of damage assessment is similar to the other foliage beetle. The beetle population can be counted on experimental plots. The adults normally disappear during hot sun and can be found resting in maize and sorghum whorls in plots with mixed cropping. The beetles can be easily controlled by the application of some insecticides including BHC, Rogor, Thiodan and Sumithion.

10.7.5 Flower thrips.

Taeniothrips sjostedti (Tryb.) is a major pest of cowpea throughout tropical Africa (Taylor, 1974). The thrips are shiny black and are found easily in cowpea flowers. It has been reported as a pest of flowers. Taylor (1965) observed thrips feeding injuries characterized by the distortion, malformation and discoloration of floral parts and suggested that these injuries, particularly on anthers and filaments, may lead to premature loss of pollen

and decrease in pollination and seed set. Singh (unpublished) observed it as a serious pest of flower buds. Severely infested plants do not produce any flowers and the damage to flower buds is more serious than to open flowers, anthers and filaments. The biology of this pest on cowpea plants is not fully known. Apparently, the adults lay eggs in flower buds and the orange-colored nymphs and adults feed on the flower buds and this reduces flower production.

The insect population is assessed either by examining the flowers or by tapping the flower buds on a hard board and counting the thrips. The damage by the thrips is measured by visually judging the flower buds for percentage of damage. Azodrin, Dursban, and Surecide were found most effective followed by BHC, DDT and Lannate. Only one application at flower bud formation stage was found effective in controlling thrips. A detailed study on resistance to this pest has not been completed at IITA. Preliminary observations indicated that TVu 1509, TVu 7274, VITA-4 and VITA-5 are moderately resistant whereas VITA-1 and VITA-3 are susceptible.

10.7.6 Stem and pod borer.

Maruca testulalis Gey. is a major pest of cowpea throughout Africa. The larva feeds on stem, peduncle, flowers and pods. Characteristic feeding symptoms are production of frass and webbing by the larvae. It was observed that if the pods touched any other part of the pod, including another pod, the portion of pod in contact was most liable for pod borer infestation, Singh (unpublished). The biology and bionomics of this pest has been studied by Taylor (1967). He indicates that the eggs are laid on flowers and flower buds. Early instars

after feeding on flowers and flower buds infest the pods. Observations made by Singh (unpublished) indicate that early-generation infestation by this pest occurs on tender parts of stem and peduncles. Later the insect multiplies within the crop, infesting flowers and pods. The larvae is easily identified due to light brown color with irregular brownish-black dorsal, lateral and ventral spots. The moth is light brown with whitish markings on forewings and nocturnal in habit. It has been reported that about 150 eggs are laid per female. The eggs hatch in about five days. There are five larval instars and the larval stage lasts about 8 to 13 days. Pupa are found in the soil. Pupal stage is 5 to 7 days. Adults have been reported to survive from 5 to 7 days (Taylor, 1977).

The pod borer damage on stem and peduncles is assessed by counting the total number of plants per plot and the number infested. Flower damage is counted by counting total number of flowers per unit area and the number of infested flowers. Similarly, the pod damage is also assessed when the pods are fully grown but are still green.

Dursban, Lanmate and Surecide were found effective at 400 gr. a.i./ha. Thiodan and BHC were found effective 800 g. a.i./ha. The insecticide should be applied at the flowering stage of the plant.

VITA-1 and VITA-3 are susceptible to this pest. VITA-4 is less susceptible, VITA-5 is resistant to stem and peduncles. Due to long peduncles, it also escapes any damage.

10.7.7 Pod sucking bugs:

There are several species of pod sucking bugs that are frequently found on cowpea plants. The most important species occuring in this region are:

Anaplocnomis curvipes F.

Acanthomyia horrida Germ.

Riptortus dentipes F.

A. curvipes is a black, fairly large coreid. Fully grown bugs are about 3.0cm long. Adults are strong fliers; when disturbed they usually fly to nearby trees. Adult bugs suck the sap of the green pods. The pods shrivel and dry prematurely. Seeds from the affected pods do not germinate well. The biology of this pest has been studied in detail by Ochieng (unpublished). Adults normally lay eggs on other leguminous plants and on weeds; seldom are eggs laid on cowpea plants. The eggs are laid in rows. The newly hatched nymphs are bright red and later turn black. The first two instars resemble ants. It has five instars and usually only adults are found on cowpea pods. It is not easy to count the insect population on small experimental plots. Percentage damage is however, assessed by counting total number of pods per unit area and the number of damaged pods.

A. horrida are light brown, sluggish coreid bugs about 1.2cm long. These pod sucking bugs are easily identified as large colonies consisting of different instars and found on green pods. Unlike *A. curvipes*, these pod sucking bugs lay eggs on cowpea plants and different instars are found feeding on the green pods. The bug has five instars which are similar. Insect population can easily be recorded on field plots.

R. dentipes are brown, about 2.0cm long, cylindrical coreid bugs with a characteristic whitish or yellow line on both sides of the ventral surface. The adults are active fliers and do considerable damage to green pods by sucking the plant sap. Eggs are normally laid on other leguminous plants, a few eggs are also laid on cowpea plants. There are five nymphal instars. It is easy to record the pest population on small experimental plots as the adults and nymphs are found on the plants. Damage assessment is recorded similarly to *A. curvipes* damage evaluation.

The pod sucking bugs are easy to control. Several insecticides including BHC, Thiodan, Azodrin and Sumithion were found effective.

10.7.8 Pod borer.

Cydia ptychora Meyr. is a tiny, dull blackish moth. The early instar larvae are whitish and later turn pinkish to bright red. Occasionally it is a serious pest of cowpea. The larvae infest pods that are near maturity. The first instar larvae enter the pod and feed on the seeds and remain inside the pod until they are about to pupate. They pupate in the soil. The biology of this pest has been described by Taylor (1965). Eggs are laid commonly on the peduncle of pods, after hatching, larvae enter the pod. There are five larval instars. *C. ptychora* can be effectively controlled by the application of insecticide when the pods are fully formed. Several insecticides, BHC, Dimecron, Azodrin and Sumithion have been found effective. Cowpea varieties resistant to this pest have been identified at IITA. The resistant varieties are close to wild, weedy types. Efforts are being made to incorporate the resistance in elite lines.

10.7.9 Cowpea storage weevil.

Callosobruchus maculatus (F.) is a small beetle with dark markings on elytra. It is a stored grain pest. The initial infestation occurs in the field and after harvest multiplies in storage. It is a serious pest of cowpea in storage. Yield losses in Nigeria are estimated at about 1.6 million dollars each year (Caswell, 1970). The common name of this pest is a misnomer. It is a bruchid and the adults, unlike weevils do not have functional mouth parts and they do not feed. Adults have a short life, about 5-8 days. They lay eggs on the seeds' surface. The larvae after hatching enter the seeds and spend the rest of the life cycle inside. Adults emerge from the seed through holes made by the larvae. The entire life cycle may take about 30 days. The damage to cowpea seed is due entirely to larval feeding inside the seed.

Cowpea storage weevil can be controlled by application of BHC, Malathion and DDVP in storage. Phostoxin fumigation tablets are also very effective. A simple method for control of this pest has been developed at IITA (Singh *et al.*, 1976). The method involves mixing groundnut oil at the rate of 5 to 10 ml. per kilo of cowpea seed. By this method, it was found out that the seeds can be stored for more than 6 months without any infestation. The treated seeds germinate well and have no bad effects on cooking or taste.

10.8 Minor pests.

There are several other pests that have been observed occasionally. These pests may not be important in this region, but may be of some importance in other regions. The other pests so far observed as minor or occasional pests are:

10.8.1 *Aphis craccivora* Koch. Sometimes these aphids have been found on cowpea plants. They multiply faster and large colonies are noticed during cool weather. Unless the aphid population is very high, practically no damage is done to the cowpea plant. The predator, lady bird beetle keeps the aphid population under control. The aphids are suspected to be vectors of cowpea viruses and indirectly may do more damage as virus vectors. The aphids are easily controlled by the application of Dimecron, Rogor and Gammalin.

10.8.2 *Nezara viridula* (L.).

This is a greenish triangular pentatomid bug. The adults suck sap from the young green pods. Sometimes the population may be high, causing economic damage. Bright colored eggs are laid on the cowpea plants and the nymphs feed on tender parts of the plant and on young pods. These bugs are easily controlled by the application of BHC, Rogor and Thiodan.

10.8.3 *Lagria villosa* and *Chrysolagria nigrobana*:

These two lagriids are often found feeding on cowpea foliage causing characteristic holes in the leaves. *L. villosa* is comparatively larger blackish beetle and *C. nairobana* is a smaller bluish beetle. These beetles may be vectors of CPMV.

10.8.4 *Apion varium*:

These are small, shiny, black weevils about 2mm long. The snout is long and slender. Larvae are small white grubs with a distinct head capsule and chewing mouth parts. Females lay eggs within the green pods. Larvae feed inside the pods, destroying the seeds. Pods have adult emergence holes about 1mm in diameter. The pest can be controlled by application of BHC, Thiodan, and Azodrin.

10.8.5 *Nematocerus acerbus:*

These are large dark brown or black weevils found feeding on cowpea foliage.

10.8.6 *Barombia hemerallis:* These are bluish beetles found feeding on cowpea foliage. They often cause serious damage to soybeans.

10.8.7 *Zonocerus variegatus:*

These grasshoppers are found only on the off-season crops grown under irrigation. The early instar nymphs move in large numbers and defoliate the crop. Adults and late instars are also often found feeding on leaves. These grasshoppers can be effectively controlled by the application of BHC, Thiodan, Azodrin and Sumithion.

10.8.8 *Euchrysops malathana* and *Virachola antalus*:

These two lycaenids can do considerable damage to cowpea flower buds, flowers and pods. Their population is high under humid rainy conditions. The larvae are dark green with a few blue spots on the body. *E. malathana,* the smaller lycanid is more common and the adults are light brown. *V. antalus* is comparatively larger and the adults are metallic purple in color. This pest can be controlled by the application of BHC, Thiodan and Azodrin.

10.8.9 *Plusia acuta* and *Spodoptera littoralis:*

These two noctuids are occasionally found on cowpea plants. The larvae are nocturnal and are voracious feeders. Sometimes due to feeding on these pests heavy defoliation of the crop has been observed. *S. littoralis* larvae vary in color that may be white, brown or green. The larvae have two pairs of dark spots on the anterior and posterior sides of the body and may also

have a few more lateral markings. Thiodan, BHC and Azodrin were found effective for control of this pest.

10.8.10 *Eldana saccharina:*

This is a pest of sugar cane and maize. On the off-season crop, it was observed as a stem borer. The larvae are light brown with distinct body segments. It is difficult to control this pest, but BHC, Thiodan and Azodrin are found effective.

10.8.11 *Diacrisia lutescens*: is also a sporadic leaf-feeder (*Arctiidae*).

10.8.12 *Mylabris farquharsoni:* The red-banded blister beetle usually feeds on the flowers of cowpea and other grain legumes. A voracious feeder, it often completely detroys flowers so that pod setting is prevented. BHC and Thiodan were found effective for control of this pest.

10.9 Assessment of pest population and damage on cowpea.

For any crop loss assessment due to a particular pest, it is important to identify the pest, population levels, and evaluate the damage by the individual pest. This is often complicated due to presence of more than one pest on the field and sometimes due to feeding of these pests on the same part of the plant. A general guide line is hereby presented for assessment of pest population and damage on cowpea. This is based on the experience obtained in the field while working on cowpea cropswith field staff and trainees in Africa. Every effort was made to keep the methods as simple as possible. However, if any suitable or improved methods are found, they should be incorporated.

The sample size mentioned is based on a plot size of 20 to 30 m^2 The sample size can accordingly be changed depending on the area to be sampled. For pest population and pest damage, about 25 random plants should be sampled per plot for each pest. Wherever plant destructive sampling is involved, it should be from plants outside the centre 3m x 3m of the plot which is reserved for yield assessment. The typical damage symptom by individual pests has been described earlier. No additional attempt is made to describe the damage again.

10.9.1 *Empoasca dolichi:*

Observations to be made at about 25 DAP. Insect populations (adults and nymphs) can be counted by turning the underside of the leaf during early hours of the day. The leafhoppers are very active during the hotter time of the day and move away from the plant with slight movement. Approximately 3 to 4 young trifoliate leaves per plant are evaluated. Leafhoppers per plant are counted.

Sweeping by insect net and D-Vac vacuum suction pump can also be used for assessment of leafhopper population. The percentage of damage is assessed by observing 3 to 4 young trifoliate leaves on each plant and subjectively judging the leaf area damaged. The typical leafhopper damage is cupping and drying of leaves.

10.9.2 *Sericothrips occipitalis:* Is a greenhouse pest. In the field it may appear under drought stress conditions. Observations for the thrips should be made at 20 DAP. The populations (adults and nymphs) can be counted by tapping a single plant on a white paper. D-Vac vacuum suction pump and an insect sweeping net can also be used.

Damage assessment is similar to the method described under leafhoppers. The typical damage is interveinal chlorosis and sometimes is difficult to differentiate from leafhopper damage.

10.9.3 *Ootheca mutabilis* and *Paraluperodes quatomernus:*

Observations to be made at about 20 DAP. Percentage leaf area damage by beetles is assessed. Insect count can be made by randomly selecting the plants.

10.9.4 *Taeniothrips sjostedti:* Insect count can be made by either counting number of thrips on flowers or by tapping individual plants at flowering stage on white paper. The damage assessment is rather difficult. The percentage of damage on cowpea flower buds is assessed and expressed in terms of percentage of damage. The number of flowers produced is also a good indication on insect population and thrip resistance.

10.9.5 *Maruca testulalis:* Number of plants having pod borer damage on stem is counted at about 35 DAP. Damage to pods is assessed when the pods are fully grown and are still green, by counting total pods and pods damaged by pod borer.

The pest population is measured by plucking total (when particular cultivar is at peak flowering or near peak flowering) flowers and counting the number of flowers and number of pod borer larvae.

10.9.6 *Anoplocnemis curvipes* and *Riptortus dentipes*: Mostly only the adult bugs are found sucking plant sap from the pods. The population can be assessed by counting the number of insects per plot or unit area. It is difficult to count the adults as they are strong fliers and nymphs are not easily noticed

on cowpea plants. The damage assessment is done by counting total pods and pods damaged by the bugs (shrivelled pods) at pod maturity stage.

10.9.7 *Acanthomyia horrida* and *A. tomentosicollis:* Both adults and nymphs are found feeding on fully grown pods. Population is assessed by counting the insects (adults and nymphs) per unit area. Damage assessment is similar to that previously described for the other pod sucking bugs.

For separating different pod sucking bug damage, it is necessary to take the count of pod sucking bugs present on the field.

10.9.10 *Cydia ptychora:* The moths lay eggs when pods are fully grown. The larval development takes place inside the pod. The pest population is assessed by counting the number of total pods and infested pods at the time of harvest. The damage is measured by counting the percentage of damaged seeds after harvest.

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CHAPTER ELEVEN

DISEASES OF COWPEAS

11.1 Introduction.

Cowpeas are attacked by at least 35 major diseases caused by viruses, fungi, bacteria and nematodes (Singh and Allen, 1980). These are responsible for the deterioration of seed quality, seed rots, seedling mortality and stem and root diseases. Thus, these diseases constitute major limiting factors to production in all geographical areas where cowpeas are grown. Yield losses can be very large depending on locality and disease. Some diseases are of local importance while others are worldwide.

Methods of disease management, including inoculation procedures and trial designs and disease assessment scales have been developed and together, these have led to the identification of sources of resistance to fungal, bacterial and virus diseases (Williams, 1977). Inheritance studies have been conducted for some of them. In view of the nature of the cropping systems of which cowpea is a part, disease control through host plant resistance has been recognised as the most practicable solution.

11.2 Plant disease, disease causal agents and their importance

The term disease can be defined as a condition in which the use or structure of any part of a living organism is not normal, or, as a harmful deviation from normal functioning of physiological processes. In plants, disease can be manifested by many types of symptoms including leaf spots, leaf discoloration, reduction in plant size, replacement of flowering

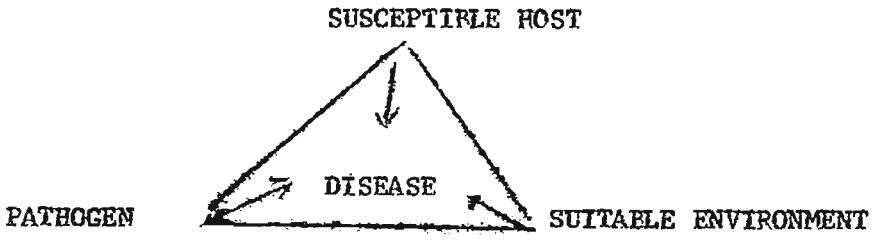
structures by leaves, root rot, stem rot and wilt. The organisms that cause disease in plants, are generally fungi, bacteria, viruses and nematodes. Recently, a new group of disease causing agents, the mycoplasma, has been recognised. Certain nutritional imbalances can also induce a state of disease in plants.

Plant diseases can reduce or completely destroy crop yield, and can reduce the quality of plant products. Major epidemics of plant disease which have resulted in far reaching effects on the health, wealth and movements of man include ergot of cereals, coffee rust, rubber leaf spot and potato blight.

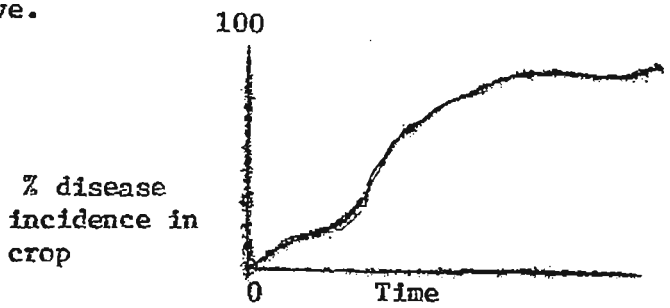
Plant disease, every year, take an enormous toll on food crop production, and represent major constraints to more intensive agriculture in the humid tropics. (For a detailed study on estimated yield losses due to plant diseases see the book by H.H. Cramer, 'Plant Protection and World Crop Production).

11.2.1 The development and spread of plant diseases.

A disease will occur if a susceptible host is in contact with a virulent pathogen under suitable environmental conditions. The relationship between these factors can be represented as the disease triangle:



In plant pathology the occurence of a disease on a single plant does not generally cause alarm. When a disease builds up in a crop so that many plants become infected major yield losses occur. The study of disease build-up and spread is known as epidemiology. The epidemic diseases generally begin in what are called primary foci and multiply within the crop throughout the growing season. The progress of disease incidence generally follows a sigmoid progress curve.



The infective agents, such as fungal spores, bacteria, and virus particles can be transmitted from one plant to another by water-splash, wind, insects or even other pathogens. (For detailed discussion on the subject of epidemic development refer to the book by J.E. van der Plank; Plant Diseases, Epidemics and Control).

11.2.2 Plant disease control.

Disease will be controlled if one or more of the factors in the disease triangle is eliminated e.g. if the susceptible host is removed by replacement with a resistant variety or non-susceptible crop, or if the pathogen is prevented from reaching the susceptible crop, or if the pathogen is prevented from reaching the susceptible host by protection of the host with a barrier or poisonous chemicals. (For a detailed discourse on plant protection methods see: Hubert Martin, The Scientific Principles of Crop Protection).

(a) The use of host plant resistance is a long practiced method for disease control. No inputs are required by the farmer, he just plants the seed of the resistant varieties. However, the relationship between hosts and pathogens is not a static relationship but is a dynamic one and because of this the use of the host plant resistance to control diseases is fraught with many difficulties. As the control of legume diseases in tropical Africa will probably have to be through the use of host plant resistance for many years, a detailed examination of the mechanisms of interaction of host and pathogen is necessary, In the 1960s several books were written on this subject, the most detailed being the two books by J.E. van der Plank: (Plant Disease, Epidemics and Control) P.R. Day, (1974) has written an excellent book on the genetics of host-parasite interactions. A summary of some of the concepts and definitions in plant disease resistance is given in the paper "Concepts of Disease Resistance" by R.J. Williams, a copy of which follows immediately). See also: Genetic Vulnerability of Major Crops, published by the National Academy of Sciences, Washington D.C. 1972).

(b) Concepts of disease resistance: First of all let us look at what we will call the 'classical' terms used to describe disease resistance (for a useful discussion of disease resistance terminology, see Robinson (1969):

(i) Immunity:: The ability to prevent infection with the effect of no disease development, i.e. total resistance;

(ii) Resistance/Susceptibility: The ability/inability to oppose or lessen the development of disease subsequent to infection; it can vary from high resistance (low susceptibility) when disease development is very limited., to low resistance (high susceptibility) when disease development is extensive.

(iii) Hypersensitivity: Describes the condition in which host cells are so highly susceptible that death occurs immediately upon infection so that when the pathogen that induces this reaction is an obligate parasite, it is sealed off and further disease development is prevented. Hypersensitivity is therefore a resistance mechanism.

Now let us go on to consider the relationship between the 'classical' terms and the 'new generation' terms such as vertical and horizontal resistance, major and minor gene resistance, race specific and race non-specific resistance. Essentially we recognise two basic types of resistance:

(i) that conferred by the action of single genes which exert a major effect and is expressed as immunity or hypersensitivity. This resistance is also called vertical resistance, (the reason for the latter term will be made clearer a little later). Refer to Robinson (1971) for a discussion of the factors governing the value of this type of resistance.

(ii) that conferred by the additive action of a number of genes, which singly exert a small effect. It is a quantitative resistance and

in effect varies from a high degree (low susceptibility) to a low degree (high susceptibility). This type of resistance has been described as minor gene resistance, horizontal resistance, field resistance, race non-specific resistance, and generalised resistance. (Refer to Robinson (1973) for a consideration of the utilization of horizontal resistance.

From the preceeding definitions it would appear that major gene resistance is the complete answer to crop protection. However, as yet we have not considered the pathogen. Disease development (or non-development) is the result of the interaction of the resistance of the host with the pathogenicity of the pathogen, and it a dynamic relationship. Let us now examine types of pathogenicity, their relationship with the types of resistance and the implications of these relationships for the utilisation of resistance for crop protection. Essentially two types of pathogenicity are recognised.

(i) that conferred by the action of a single gene which exerts a major effect, is qualitative in action, and is expressed as virulence;

(ii) that conferred by the additive action of a number of genes, which singly exert a small effect. It is quantitative in effect and is expressed as fitness or aggressiveness.

The different types of resistance and pathogenicity are summarised in Table 11.1

Table 11.1: Summary of the classification of resistance and pathogenicity:

Host	Pathogen
1. Major gene/vertical/ race specific/ qualitative resistance	1. Major gene/quantitative pathogenicity or virulence
2. Minor gene/horizontal/race non-specific/quantitative resistance	2. Minor gene/quantitative pathogenicity or aggressiveness.

For a pathogen, P to be able to infect a host H, P must possess virulence genes to match any major genes for resistance in H, i,e. there is a gene for gene relationship between major resistance and virulence - a subject covered in great detail by Person (1959).

The degree of disease development in H will be dependent upon the interaction of the aggressiveness of P with minor-gene resistance (or susceptibility) of H: e.g. take 4 varieties of H, one with no major genes for resistance (Ho) and the other three with major genes 1,2 and 3 respectively (H_1, H_2, H_3) similarly take four biotypes (races) of P one with no virulence genes (Po) and three with virulence genes 1, 2 and 3 respectively P_1, P_2, P_3). In Table 11.2 shown below, the relationship between the virulence genes and major genes for resistance is clearly shown.

Table 11.2: The interaction of four varieties of host H with four physiologic races of pathogen P.

	H_o	H_1	H_2	H_3
P_o	+	-	-	-
P_1	+	+	-	-
P_2	+	-	+	-
P_3	+	-	-	+

\+ = susceptible reaction

\- = resistant reaction.

P_o, P_1, P_2 and H_3 are physiologic races of P, i.e. physiologic races of a pathogen are characterised by the virulence genes they possess. From Table 11.2 it is clear why major gene resistance is described as race specific resistance. Major gene resistance appears very attractive for the plant breeder. A single gene with a major effect is relatively easy to identify and manipulate, and when put into a variety,confers complete resistance. This type of resistance has proved both valuable and disastrous. Major gene resistance, by virtue of its single gene basis, has the inherent "instability" of being easy to "break down". For example, in an epidemiological unit (Eu) there may be three virulence genes (1,2 and 3) present in the population of pathogen P. Varieties of host H are screened for resistance to these virulence genes and the major resistance gene H_4 is discovered. This H_4 gene is put into a suitable variety and, by virtue of its resistance to P becomes widely adopted in the Eu.

However as it becomes widely adopted it presents P with a tremendous selection pressure for the virulence gene E_4. Once E_4 occurs then it has a large area of H on which it can develop - an epidemic of P occurs on H and the resistance of variety H_4 is said to have broken down. (This is obviously a mis-statement for the powers of H_4 remain the same, it is the pathogen which has changed). When H_4 is matched by P_4 then the breeder begins another search and comes up with H_5 and the story is repeated. The attempts to control with major genes stem rust of wheat and oat crown rust in North America furnish good examples of the recurring battle between breeder and pathogen and it is likely to occur at a faster pace in the tropics. Thus, due to their race specific nature, major genes offer only a short term control of epidemic diseases. If race specific resistance is used the plant breeder has to continually concern himself in keeping one step ahead of the pathogen. If a more stable resistance can be utilised then the plant breeder can devote more time to other heritable components of yield. The key word is stability, and below we will briefly review some suggested methods for the production of stable, effective resistance.

11.2.3 Incorporation of several major genes into one variety.

The theory behind this suggestion is that the probablity of several required mutations/recombinations occuring simultaneously is far lower than that of single mutation/recombination. So a variety with several major genes for resistance will not 'break down' so quickly as a variety with a single major resistant gene. This is fine in theory but let us examine the development of such a variety. Imagine that there are four varieties of host H, and each possesses a different single major gene for resistance to pathogen P (i.e. varieties H_1 H_2 H_3 and H_4). All have been introduced singly to the

population of P and in due course have all 'broken down' due to the appearance of physiologic races P_1 P_2 P_3 and P_4. It is decided to build variety H_{1234} so that any one of the races $P_1P_2P_3$ and P_4 will have to undergo three simultaneous mutations/recombinations to be able to attack the new variety. The construction of $H_{1\ 2\ 3}$ and H_4 is possible only if

(i) the genes $H_{1\ 2\ 3\ 4}$ are on different loci;

(ii) the progeny of the crosses between the varieties can be tested for the presence of H_{1234}.

It is the latter proviso which casts doubt on the usefulness of such a variety. For how can H_{1234} be proved without races P_{123}, P_{124}, P_{1234} and and P_{134} to use in the test, see Table 11.3.

If P_{123}, P_{1234}, P_{134}, and P_{124} already exist in the population of pathogen then each will only require a single mutation/recombination to virulence to 'break down' H_{1234} which is the situation which was to be avoided. Of course if the variety H_{1234} is taken for use to where P_{123}, P_{234}, P_{134} and P_{124} do not exist, then it could be a more stable variety depending upon the mutation and recombination rate of the particular pathogen. The combination of several major genes into a single variety could also have an indirect effect on susceptibility even when 'broken down' if the particular pathogen was subject to a decrease in fitness or aggressiveness as it increased in virulence. Van der Plank (1968) cites examples of increases of virulence in *Phytophthora infestans*, *Puccinia graminis tritici* and *Melampsora lini*, being accompanied by decreases in aggressiveness, and this is the basis of the theory of stabilising selection.

11.2.4 The use of multilines i.e. several 'varieties' each with different single major genes planted in a mixture:

Van der Plank (1968) discusses the mechanism of action of multilines in the following manner: Consider that for pathogen P there are four major genes H_1, H_2, H_3, H_4 and these are used in multilines. The reaction pattern of the components of a multiline with all possible races of P is given in Table 11.4.

Table 11.3: Reaction pattern of multiline H_1, H_2, H_3 and H_4 with races of pathogen P.

	H_1	H_2	H_3	H_4
P_1	+	-	-	-
P_2	-	+	-	-
P_3	-	-	+	-
P_4	-	-	-	+
P_{12}	+	+	-	-
P_{13}	+	-	-	-
P_{14}	+	-	+	+
P_{23}	-	+	+	-
P_{24}	-	+	-	+
P_{34}	-	-	+	+
P_{123}	+	+	+	-
P_{134}	+	+	-	+
P_{234}	-	+	+	+
P_{1234}	+	+	+	+

+ = susceptible - = resistant.

Table 11.4: Reaction of various resistance genotypes of H to various virulence genotypes of P.

	H_1	H_2	H_3	H_4	H_{12}	H_{13}	H_{14}	H_{23}	H_{24}	H_{34}	H_{123}	H_{124}	H_{234}	H_{134}	H_{12}
P_1	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P_2	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-
P_3	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-
P_4	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
P_{134}	+		+	+	-	+	+	-	-	+	-	-	-	+	-
P_{123}	+	+	+	-	+	+	-	+	-	-	+	-	-	-	-
P_{124}	+	+	-	+	+	-	+	-	+	-	-	+	-	-	-
P_{234}	-	+	*	+	-	-	-	+	+	+	-	-	+	-	-

\+ = susceptible reaction
\- = resistant reaction.

Race P_{1234} has virulence for all components of the multiline, but due to its possession of several virulence genes its fitness or aggressiveness is reduced. Races P_{123}, P_{134}, P_{234} have virulence for three of the four components i.e. their spread throughout the crop is restricted by having 25% of the plants resistant to each. Their fitness is also reduced by the possession of three virulence genes. If we continue to the races P_1, P_2, P_3 and P_4, these will be potentially the most aggressive races but 75% of the plants in the crop are resistant to any of them. In this multiline all fifteen possible races of P would have their pathogenicity reduced either because of reduction of

fitness, from obstruction to spread, by possible induced resistance (Johnson and Allen, 1975), or a combination of these. The net effect would be to reduce infection rate of P and thus the multiline would behave in much the same way as a horizontally resistant variety. Browning and Frey (1969) gave a detailed discussion of multilines and conclude with the sentence "Being easy to develop, they (multilines) hold great promise as a dynamic, natural biological system of effectively buffering the host population against the (in this particular discussion) rust population.

11.2.5 The use of horizontal resistance:

A high degree of horizontal resistance (low susceptibility) should theoretically provide a far more stable resistance than vertical resistance for the prevention of disease epidemics. The resistance is not absolute so it will not exert tremendous selection pressure on the pathogen population for evolution of new races and by virtue of its polygenic basis is not subject to sudden breakdown. The work of Niederhauster, Cervantes and Servin (1945) with late blight of potato give a clear example of the practical use of horizontal resistance. Niederhauster states that polygenic resistance to *P. infestans* has demonstrated acceptable stability in 10 years of field trials in Toluca, Mexico, where annual epiphytotics occur and physiological races are prevalent. He indicates that in certain selections there has been some 'erosion' of resistance but no sudden breakdown has occurred. It has been suggested that because of its polygenic basis, horizontal resistance is difficult to accumulate in a breeding programme. However plant breeders manage to work other polygenically controlled characters such as yield so perhaps the problem

is one of not knowing how to go about selection rather than a lack of technology to manipulate the resistance once identified. What selection methods are to be used for the selection of a high degree of horizontal resistance? There must be a careful examination of those factors which affect the spread of disease within a crop. Such epidemiological parameters include:

(i) The infection ratio (the number of resulting lesions as a percentage of the spore dose applied);

(ii) The incubation or latent period (the period from inoculation to the first production of spores);

(iii) The sporulation rate (the quantity of spores produced per lesion per unit time);

(iv) The sporulation or infectious period (the period during which lesions sporulate).

At IITA we believe we must go for high degrees of horizontal resistance. We have begun to experiment in the field, glasshouse and growth chamber, on plots, individual plants and even detached leaf segments in our search for efficient techniques to assess those host factors which determine the degree of horizontal resistance.

(c) Chemical control of plant diseases: Many chemicals are known which are toxic to disease causal agents. However their usefulness depends upon the economics of their application and the safety of their use and residues in human food. For legume disease control in tropical Africa, it is unlikely that the use of fungicides or bactericides will be profitable except in the

area of seedling diseases and so it is the efforts of the geneticists and plant breeders working with pathologists that can be expected to have the major technological impact in the control of legume diseases in Africa in the next decade.

Key references for introduction to plant pathology:

(a) The importance of pests and diseases to world food crop production.

(i) The Need for Intensified and Integrated Campaigns Against Pests and Pathogens of Economic Plants by E.C. Stakman.

(ii) Plant Protection and World Crop Production by H.H. Cramer. Published by Farben abriken Bayer AG. Leverkusen.

(b) Plant pathology and the major groups of plant pathogens.

(i) Principles of Plant Pathology by E.C. Stakman and J. George Harrar (1957) Ronald Press Company, New York.

(ii) The Principles of Plant Pathology by S.A.J. Tarr (1972). London Macmillan.

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11.3 Viral diseases.

The viral diseases of cowpea have received more attention in Nigeria than any of the other diseases of this crop. Today active work on cowpea viruses is conducted at the University of Ife and its Institute for Agricultural Research and Training at Ibadan, the University of Ibadan, Ahmadu Bello University at Samaru, the Federal Department of Agricultural Research at Ibadan (now the National Cereals Research Institute), and at the International Institute of Tropical Agriculture (IITA). The effects of viral diseases can be devastating in cowpeasand they remain a major constraint to large scale cowpea production, particularly in southern Nigeria.

11.3.1 Cowpea (Yellow) mosaic virus:

Smith (1924) described a mosaic disease of cowpea in the southern U.S.A., caused by a virus transmissible by the leaf beetle *Ceratoma trifurcata* Forst., but he did not further characterise the virus. Dale (1949) reported a seed borne cowpea mosaic virus (CPMV) from Trinidad, which was transmitted by the related bean leaf beetle *Ceratoma ruficornis* Oliv. Chant (1959) reported a virus widely distributed on cowpeas in south eastern and south western Nigeria, which was also transmitted by a beetle (*Ootheca mutabilis* Sahlb) and which he called cowpea yellow mosaic virus (CYMV). On the basis of host range and

physical properties, Chant regarded CYMV and the Trinidad CPMV to be different viruses. Sheperd and Fulton (1962) reported a cowpea mosaic virus disease form Arkansas, which was serologically related to the Trinidad CPMV, to the bean pod mottle virus, and to the Nigerian CYMV (Sheperd, 1963). Agrawal (1964) examined three isolates of cowpea mosaic virus from Surinam and compared these with the Trinidad CPMV and with the Nigerian CYMV. He concluded that all isolates belonged to cowpea mosaic virus (CPMV). Swaans and Van Kammen (1963) made a detailed comparison of the Nigerian CYMV and a Surinam strain of CPMV and whilst they found distinct phenotypic and genetic differences between the two virus isolated, they concluded that for practical reasons the CYMV and CPMV isolates should be regarded as strains of the cowpea mosaic virus group. Similarly, Bozarth (personal communication, 1975) has compared Nigerian isolates of CYMV with Puerto Rican isolates to which they were weakly related serologically, the latter are probably referrable to the severe strain of cowpea mosaic of Swaans and van Kammen (1973).

The symptoms produced by CYMV vary greatly with cowpea variety and with CYMV isolate. Following mechanical inoculation the plant may show no reaction, necrotic local lesions of two distinct types, or chlorotic local lesions. Positive systemic reactions vary from barely discernible green mosaic to complete death of the plant. In a recent screening of more than 500 cowpea lines at IITA (William, 1975a) it was found necessary to record separately local lesion reaction, presence and density of systemic necrotic spotting, and reduction in plant size, for each of these symptoms varied in intensity and could occur singly or in various combinations.

The Galerucid beetle *Ootheca mutabilis* Sahlb, was described as the vector of CYMV by Ghant (1959). Recently, however, several other insects including two thrips (*Sericothrips occipitalis* Hood and *Megalurothrips sjosdedti* Tryb.), the chrysomelid beetle *Paraluperodes quaterus* Fairmaire (= *Luprodes lineata* Kars.) the curulionid beetle Nematocerus acerbus Fst. and two grasshoppers (*Cantatops spissus* Wlke., and *Zonocerus variegatus* F.) were shown capable of transmitting CYMV in cowpeas (Whitney and Gilmer, 1974). Caveness *et al.* (1974) have shown that the nematode *Xiphinema basiri* may also transmit CYMV.

CYMV, is seed borne but generally at a low level (1-5%) (Gilmer *et al*, 1974). With the massive insect activity on cowpeas from the seedling stage onward, CYMV incidence can build up rapidly in the crop from a small proportion of seed-borne infection, to reach 100% by maturity.

Yield reductions of 60-100% due to CYMV infection are reported (Chant, 1960; Shoyinka, 1974; Gilmer *et al* 1974). The earlier the infection the greater the yield reduction, although even with infections as late as six weeks after planting, significant yield reductions occur (Chant, 1960).

Possible methods of control include vector control with insecticides, and the use of resistant varieties. In experimental fields at IITA the incidence of CYMV is kept at low levels by weekly applications of insecticides although complete control of the disease is not achieved. Roguing of infected plants as soon as they show symptoms also aids the minimization of spread (1975) attempted control of virus incidence in cowpeas at three locations in the Western State of Nigeria by spraying with insecticides and by the use of mixed cropping.

Sprayed plots had fewer infected plants than unsprayed (though the difference was not statistically significant) and intercropped cowpeas had fewer infected plants than any other treatment. However the control of CYMV by the use of insecticides for vector control is unlikely to be technically successful at peasant farmer levels.

The best means of control appears to be the use of resistant varieties. Wells and Deba (1961) screened 116 introduced cowpea varieties and 342 indigenous pure lines against a single isolate of CYMV and found six varieties and 16 pure lines to be resistant. Robertson (1965) screened 79 cowpea varieties against two CYMV isolates and classified 16 varieties as immune (no local lesions, no systemic symptoms and no virus recovery), eight varieties as resistant (necrotic local lesions but no systemic symptoms), and 38 varieties as susceptible with chlorotic local lesions and systemic infection. Seven lines gave differential response to the two CYMV isolates in Robertson's tests. Recently at IITA 543 cowpea lines were screened for their reactions to two isolates of CYMV (Williams, 1975a), and unlike Robertson, found no consistent relationship between local lesion reaction and susceptibility. In the IITA test 52 lines developed no systemic symptoms and were designated as highly resistant, 29 lines had mixtures of symptomless and infected plants and were probably segregating, 75 lines developed only mild mosaic with no leaf distortion or stunting and were designated resistant, and 41 lines showed a differential response to the two isolates. Robertson (1965), Williams (1975a) and Allen (1976) have found differential pathogenic strains of CYMV in Nigeria.

Although this complicated the development of resistant varieties because

broad-spectrum resistance is required, some promising lines have been identified. Though Victor K798 (TVu 1043) and VITA 3 (TVu 1190) each possess resistance to many isolates of CYMV, they have been found to be susceptible to newly obtained isolates (Allen, 1976).

11.3.2 Cowpea mottle virus.

Robertson (1963) reported a second important virus in cowpea, which he called cowpea mottle virus (CMeV). It causes a conspicuous leaf mottling and distortion in many local varieties and is distributed throughout western and eastern Nigeria. In northern Nigeria, CMeV occurs in *Voandzeia subterranea*. The virus is as stable in vitro as CYMV but its host range is more limited and it is not serologically related to CYMV. CMeV is easily transmitted mechanically but its natural vector is unknown. The evidence from yield trials indicates that the effect on the yield of susceptible varieties is of the same order as that due to CYMV. The varieties Bechuana, New Era, Qlqbumh and Dixielee selection were found tolerant to CMeV and tolerance was dominant to susceptibility with either one or two genes responsible depending on the variety (Bliss & Robertson, 1971).

Recently, Rossel (1976) has found that electron micrographs of purified preparations of CMeV have apparently revealed the presence of spherical virus particles of two different sizes, suggesting a satellite virus may be involved.

11.3.3 Tobacco mosaic virus (cowpea strain):

Lister and Thresh (1955) described a mosaic disease of cowpea in Nigeria caused by a strain of tobacco mosaic virus. Unlike other strains it infected

cowpea and Bengal bean (*Mucuna aterrima* Holland) systemically and also produced systemic symptoms in French bean (*Phaseolus vulgaris* L.). The virus caused local lesions in inoculated tobacco leaves (*Nicotiana tabacum* L.) followed later by systemic infection. Bawden (1956) established that this strain had certain distinctive physical properties and was similar to one from India isolated from sunn hemp (*Crotalaria juncea* L.)/ Chant (1959) showed that the beetle *O. mutabilis* transmitted tobacco mosaic virus from Bengal bean to Bengal bean and cowpea, and from cowpea to cowpea and Bengal bean. Chant (1959) reported that infection of cowpea with the cowpea strains of tobacco mosaic virus does not cause yellowing but produces only a mild green mottle on the leaves, and that only a small proportion of virus infected cowpea plants contain tobacco mosaic virus. Chant (1960) found that infection of cowpea with tobacco mosaic virus cowpea strain did not affect yield as much as infection with CYMV.

11.3.4 Cowpea aphid-borne mosaic virus:

Raheja and Leleji (1974) reported the occurrence in northern Nigeria of an aphid-borne virus disease of cowpea grown under irrigation, which was apparently responsible for complete loss of a cowpea crop in 1973. The virus caused a widespread mottling, interveinal chlorosis and vein banding. Infected plants became stunted and bushy, and flowering was retarded and inhibited. Field incidence reached almost 100%, resulting in virtually a total crop loss in five out of six plantings. Although Raheja and Leleji (1974) were unable to transmit the virus(es) by sap and found no evidence of seed transmission, on the basis

6f its transmission by *Aphis craccivora*, they concluded that the virus was either a strain of cowpea aphid-borne mosaic virus (CAMV) or a new virus.

Rossel (1976) has recently shown that the host range, the comparatively low particle, concentration, sap, aphid and seed transmissibility and electron microscopy of a cowpea virus present in farmer's fields in northern Nigeria conform to those of CAMV. Ladipo (1976) has provided evidence that the % seed transmission of Nigerian CAMV depends on the host genotype. Work is in progress on screening for sources of resistance to CAMV.

CAMV is known to be widespread in East Africa (Bock, 1973) and sources of resistance to a virus presumed to be CAMV have been located by Patel in Tanzania. CAMV, which in Africa is also known to occur in Morocco, (Fiecher) and Lockhart, 1976), has been fully described by Lovisolo and Conti(1966) and Bock and Conti (1975).

11.3.5 Cowpea mild mottle virus:

A previously undescribed virus is widespread in cowpeas in the Eastern Region of Ghana. The virus has filamentous particles, is seed-borne in cowpea and is readily sap transmissible. No vector is known. The virus has been called cowpea mild mottle virus (CMMV) (Brunt and Kenten, 1973; 1974). CMMV occurs also in Kenya where it is more frequent in groundnut.

11.3.6 Cowpea chlorotic mottle virus:

Cowpea chlorotic mottle virus has a temperate distribution and is reported only from North America (Bancroft, 1971).

11.3.7 Cucumber mosaic virus:

Two strains of cucumber mosaic virus (CMV) have been found in Nigerian cowpeas in which the virus is transmitted by aphids and to a lesser extent in seed (Shoyinka 1974). Sources of resistance in cowpeas to CMV have been located and shown to be controlled by a single dominant gene pair (Sinclair and Walker, 1955). The properties of CMV have been summarised by Gibbs and Harrison (1970).

11.3.8 Southern bean mosaic virus:

The cowpea strain of Southern bean mosaic virus was recently reported from western Nigeria by Shoyinka (1974), Shoyinka and Okusanya (1975) and Ladipo (1975), and from Ghana by Lamptey and Hamilton (1974). SBMV apparently has not yet been reported from elsewhere in Africa though it is known from warm temperate and tropical areas of America (Shepard, 1971).

SBMV is seed-borne in cowpea (Shepherd and Fulton, 1962; Lamptey and Hamilton, 1974), is readily sap transmissible and transmitted by the beetle, *Ceratoma trifurcata*, in North America (Walters and Henry, 1970). The virus' vector in Africa is unknown though this is currently under study at IITA.

Kuhn and Brantley (1963) in North America and Lamptey and Hamilton (1974) in Ghana, and Ladipo, Allen and Shoyinka (unpublished results) in Nigeria, have identified sources of resistance in cowpeas to SBMV. The 4 types of response usually observed were: (1) symptomless (either immune or tolerant), (2) hypersensitive, (3) hypersensitive plus systemic necrosis, and (4) varying levels of susceptibility.

Hypersensitivity has been found to be controlled by a single dominant gene pair (Brantley and Kuhn, 1970).

11.4 Fungal diseases.

The check list of plant diseases in Nigeria (Bailey, 1966) lists 18 fungi causing diseases on or colonising cowpea. However, apart from this check list, there has been little information published on the cowpea fungal diseases in Nigeria until about 1974. Since 1970 the fungal diseases of cowpea have received major attention in the IITA Grain Legume Improvement Program and several diseases have been shown to represent major constraints to intensified cowpea cropping and increased cowpea production.

11.4.1 Seedling mortality:

Grain legumes are particularly vulnerable to attack by soil-borne pathogens during the first two to three weeks of their development. Cowpea seedling mortality of 75% by 21 days after planting(DAP) is reported from the forest region of southern Nigeria (Williams, 1975b).

The major seedling pathogens are *Pythium aphanidermatum* (Edson) Fitzp. *Rhizoctonia solani* Kuehn (*Thanatephorus cucumeris* (Frnk.) Donk.) (IITA, 1971). Both pre- and post-emergence mortality occur, and in the latter case characteristic symptoms can be observed on the hypocotyls. The reddish-brown lesions caused by *R. solani* are usually limited to the collar region of the hypocotyl at which point the diseased seedling topples. *P. aphanidermatum*, however, moves rapidly up the hypocotyl giving it a grey-green wet appearance and the seedlings undergo a watery collapse. The incidence of the disease varies

throughout the growing season. At Ibadan at the beginning of the rains when the soil has been hot and dry for five months and rainfall is sporadic the incidence is low, whereas during the cool wet overcast weather of June and September the incidence is high (Williams, 1975b). The majority of the peasant farmers employ no control measures against this disease. Seedling rates are increased to allow for the mortality. It is unlikely that resistance can be found to these unspecialized soil-borne pathogens at the seedling stage. The most promising means of control appears to be the use of systemic fungicides as seed dressings prior to planting. The systemic fungicide chloroneb (demosan), used as a dry seed dressing at the rate of 2g product/kg seed, has given a stable high level control of this disease in 12 field trials at various locations in southern Nigeria (Williams, 1975b). However, this control measure is unlikely to be utilized by the peasant farmer unless the fungicide is readily available and is packaged in small quantities purchasable for a few small coins.

11.4.2 Anthracnose:

Cowpea anthracnose, caused by *Colletotrichum lindemuthianum* (Sacc. & Magn) Bri. & Cav. was first recorded in Nigeria in 1969 at the University of Ife farm (Onesirosan and Barker, 1971). The disease is particularly severe in monocropped cowpeas and spreads rapidly during cool wet weather. All above-ground parts of the plant can be infected. Individual lesions are lenticular to circular, sunken, and tan to brown colour. Lesion size and distribution depend upon varietal susceptibility. Highly susceptible lines develop large spreading lesions, which rapidly coalesce to girdle stems, branches, and peduncles and

petioles, so that these parts appear almost completely brown. Brown sunken lesions also occur on pods, but the symptoms on the stems and branches are always more severe. Resistant lines develop a few small narrow lesions, mainly towards the ends of trailing branches. Many lines exhibit hypersensitive reactions, which vary from tiny necrotic flecks to lenticular shiny reddish-brown lesions up to 5mm long. No sporulation occurs in these hypersensitive lesions. The pathogen is seed-borne in cowpea up to about 40% (Onesirosan and Baker, 1971). Based on its morphological and cultural characteristics the pathogen has been consistently identified as *C. lindemuthianum* at the Commonwealth Mycological Institute, Kew, England. However, it appears to be pathogenically distinct from the bean (*Phaseolus vulgaris* L.) anthracnose organism for it is non-pathogenic on the bean cultivars Michellite, Black Valentine and Dark Red Kidney (R.J. Williams, unpublished), which together are susceptible to six major races of the bean anthracnose organism (Goth and Zaumeyer, 1965, Leakey and Simbwa-Bunnya, 1972).

Grain yield reductions of 35-50% have been measured in a mono-crop culture of a highly susceptible line when the disease was introduced at an early stage in crop growth (Williams, 1974). However the buildup of the disease is likely to be much slower in the mixed-cropped peasant farms than in mono-cropped cowpeas.

The disease can be partially controlled with weekly or bi-weekly applications of benomyl or mancozeb (0.2% a.i.) (IITA, 1974) but the method is costly and requires labour and technical know-how, both of which are limited at the farm level. As indicated above, mixed cropping does afford protection

from rapid epidemic development but this method of control precludes more intensive cropping of cowpea. The most promising means of control is the utilisation of host plant resistance. In screening the cowpea germplasm collection at IITA three types of resistance have been identified(a) immunity (b) hypersensitivity which is a functional immunity (c) field resistance, which allows little or no anthracnose development in field disease nurseries, even though young stem and petiole tissues are susceptible when subjected to innoculations in the laboratory with high inoculum concentrations and ideal conditions for infection.

The detached technique has provided a rapid method for screening for immunity and hypersensitivity to anthracnose and, more recently, it has been found possible to detect "field resistance" in the laboratory by a modification of the same method (Skipp, 1975). There is evidence that hypersensitivity may be under the control of one or a few genes thus rendering it liable to "breakdown"; should it emerge that "field resistance" (present in TVu 76, 647 and 1190) is polygenically determined, it is probable it will be more stable. While the mechanism of field resistance has been shown to be essentially a delayed hypersensitive reaction (Skipp, 1975), its inheritance has yet to be elucidated.

11.4.3 Cercospora leaf spots.

The fungi *Cercospora canescens* Ellis & Martin and *Cercospora cruenta* Sacc. both cause leaf spots on cowpea in Nigeria. *C. canescens* produces roughly circular cherry red to dark-red spots of up to 10mm diameter and when these are numerous the leaves turn yellow and absise.

C. cruenta spots begin as a chlorosis on the adaxial surface which become dotted with necrotic spots that enlarge until the whole lesion area is necrotic and coloured brown. On the abaxial leaf surface the *C. canescens* lesions are also coloured red whereas the abaxial surface of leaves infected with *C. cruenta* exhibit areas of profuse sporulation of the casual fungus in which the masses of conidiophores appear as downy gray-black matts. Symptoms are not usually seen until flowering time. In susceptible varieties disease build-up can be rapid and severe premature defoliation occurs.

Although both diseases can occur with high incidence, *C. cruenta* leaf spot is more important, at least in the Ibadan area, for it occurs in all seasons whenever susceptible lines are planted. Only occasionally does *C. canescens* leaf spot occur with sufficient intensity early enough in the crop growth to cause significant losses. Cowpea grain yield reductions of about 20% and 40% have been attributed to *C. canescens* and *C. cruenta* respectively (IITA 1973).

Both species can be found sporulating on pods, especially during wet weather, and they are seed borne in cowpea. These two pathogens can be completely controlled with foliar applications of the systemic fungicide benomyl (0.2% a.i).

Many lines resistant to both pathogens have been identified in the IITA screening program, and are now being tested in several countries, including Puerto Rico, Brazil and India, for stability of resistance to several different populations of the pathogens under widely differing environments.

Sources of resistance to *C. cruenta* have also been identified in America by Fery *et al.*, (1976) who have shown that such resistance may be controlled by either a single dominant or single recessive gene.

11.4.4 R u s t:

Rust caused by *Uromyces appendiculatus* (Pers.) Ung. (syn. *U. phaseoli* (Pers.) Winter var. *vignae* Arth. and *U. vignae*-Barcl.) is a widespread and important disease of cowpea in Nigeria. Highly susceptible lines can be almost completely defoliated by mid-flowering time, resulting in severe yield reduction. At Ibadan rust builds up rapidly in dry-season irrigated plantings and during the sporadic rains at the beginning and end of the rainy season. During the heavy rainfall months of June and September however, the spread of this disease is markedly reduced.

On young cowpea plants the leaves become covered in small pustules containing the light brown uredospores. Plants with heavy rust infestation appear to have a brown tinge from a distance, and wilt quicker than rust resistant lines during periods of sporadic rainfall. As the plants age those leaves not completely destroyed produce the characteristic black masses of teleutospores.

Two other rust fungi occur on cowpeas in Nigeria. One (*Phakopspora pachyrhizi* Syd.) produces bright orange pustules on leaves, stems, peduncles and pods, though occasionally the pustules are confined to under-surfaces of leaves where they are pinkish in colour. The other species is *Aecidium caulicola* which is associated with a basal stem swelling (IITA, 1976).

11.4.5 Pythium stem rot:

In addition to seedling mortality, *Pythium aphanidermatum* (Edson) Fitzp. also induces a stem rot in adult cowpea plants (Onuorah, 1973; Williams and Ayanaba, 1975). Pythium stem rot (PSP) is characterised by a grey-green water-soaked girdle of the stem extending from soil level up to and sometimes including the lower portions of the lower branches. The infected area is slimy to the touch, and the stem cortex, which becomes packed with oospores of the causal fungus is easily stripped off. During periods of high humidity copius growth of white cottony mycelia occurs at the stem base. Infected plants rapidly wilt and die. Following the death of the plant the infected area dries and is often colonised by other fungi including *Myrothecium roridum* Tode ex Pre. and *Colletotrichum capsici* (Syd.) Butler and Bisby.

Field incidence normally ranges between 0.5-10.0% although occasionally fields are seen with more than 30% of plants killed by PSR. The use of benzimidazole fungicides to control Cercospora leaf spot or anthracnose greatly increases the incidence of PSR (Williams and Ayanaba, 1975).

In two seasons trials with several fungicides by weekly applications of captafol proved effective for the control of PSR (IITA, 1974, IITA 1975). No systematic screening for resistance to PSR has been undertaken. However, observations at the Federal Department of Agricultural Research Ibadan (Onurah, 1973) and in variety trials over several seasons at IITA indicate differences in varietal susceptibility to the disease. Some recent progress has been made at IITA in the development of a rapid screening technique to identify

sources of resistance to PSR, depending upon the induction of zoospores as inoculum.

11.4.6 Web blight:

Cowpea web blight, caused by *Rhizoctonia solani* Kuehn (*Thanatephorus cucumeris* (Frank) Donk.) is a disease of increasing significance as cowpea production is moved south from the savannah to the forest region. The pathogen infects the leaves and young stem tissue and can totally destroy the leaf canopy of the crop during periods of heavy rain with continuous overcast skies. The initial symptoms on the leaves are small circular brown spots. These enlarge, often showing concentric banding, and become surrounded by irregular shaped water-soaked areas. During long periods of high humidity the lesions expand rapidly and coalesce and mycelium of the casual fungus can be clearly observed under surface of the leaves and young stems.

The pathogen has a wide host range and is soil borne. Initial inoculum comes mainly from soil splashed onto leaves during heavy rain. The key factor in the establishment and build-up of the disease in the cowpea crop is humidity. It is a disease enhanced by high rainfall and overcast skies and appears to be one of the major constraints to growing monocrop cowpeas in the forest region of southern Nigeria.

In the short term, cultural methods offer the best means of control. Dense plantings should not be made and planting should be timed to avoid the peak rainfall periods.

Experiments with various mulching practices should be tried to see if inoculum levels can be reduced. The literature is not encouraging on the control of web blight by host plant resistance for the odds seem to be against finding varietal resistance to a fungus such as *Rhizoctonia solani*, which is not selective in its parasitism. Leach and Garver (1970) concluded that in general, while it has been possible to identify differences among varieties or selections in susceptibility to *Rhizoctonia* infection, it is extremely rare that a high degree of resistance has been found, or produced by selection or breeding, within a susceptible host species. In Nigeria work is in progress at the University of Ife and IITA to find methods for dectection of small differences in susceptibility, which may be utilized with cultural methods to attain an acceptable level of control. Results from preliminary field tests (Oyekan 1976) have shown that TVu's 317, 1282 and 4539 may possess some resistance, while laboratory screening has identified further lines with apparent low susceptibility, though the ultimate validity of the latter results requires examining from further field screening (Allen and Ogunseinde, unpublished results, 1976).

11.4.7 Corynespora leaf spot.

As the cowpea is maturing many varieties develop a high incidence of *Corynespora* leaf spot or target spot, caused by *Corynespora cassiicola* (Berk. & Curt.) Wei. The lesions begin as dark reddish-brown circular spots 1-2mm diam. which expand with marked narrow concentric banding to become large target spots up to 15mm diameter. The fungus also produces dark reddish-brown lesions on petiole and stems but these remain small (1-3mm diam.) and do not show concentric banding.

Although this disease can look spectacular on highly susceptible cowpea lines it probably causes little yield reduction due to its appearance at a late stage in crop development.

Varieties differ in susceptibility to this disease and several sources of immunity have been detected in the germplasm collection at IITA.

11.4.8 Septoria leaf spot:

Septoria leaf spot caused by *Septoria vignae* P. Henn. is characterised by bright red to dark red roughly circular to irregular spots 2-4mm wide which appear almost identical on the upper and lower leaf surfaces. This disease can be distinguished from *Cercospora canescens* leaf spot by its smaller and more concentrated spots, which give the leaf a freckled appearance. Heavily spotted leaves turn yellow and abscise.

Septoria leaf spot is seen only occasionally in the wetter forest region in the south and is more important in the savannah region. In 1973 the disease was severe in plots of Prima cowpea and a breeding line 27-b-8-1-b at Samaru and Kano in northern Nigeria. Observations at Kano and Samaru indicate apparent varietal differences in susceptibility, which could be exploited.

11.4.9 Other fungal diseases:

Numerous other fungal diseases are of local or seasonal importance. Powdery mildew, caused by *Erysiphe polygoni* DC ex Merat, in Nigeria is merely a nuisance in greenhouse cowpeas, appears late in the growth of field crops after the end of the rains; it may be of greater economic importance.

Zonate leaf spots caused by *Ascochyta phaseolorum* Sacc. and *Dactuliophora tarrii* Leakey and false rust (*Synchytrium dolichi* (Cooke) Gaum. are among

the most important foliar pathogens in certain areas of eastern Africa (Mukibi, 1969). *Sclerotium* stem rot, caused by *Corticium rolfsii* Curzi (*Sclerotium rolfsii* Sacc.), infects the bases of stems producing a thick web of mycelium and large white round sclerotia that turn dark brown, and can completely kill the infected plant. *S. rolfsii* may also induce a leaf spot. Premature senescence is caused by the sclerotial stage (*Rhizoctonia bataticola* (Taulb.) Butler) of *Macrophomina phaseoli* (Tassi) Goid. A wilt of cowpeas, caused by *Fusarium oxysporum* f. sp. tracheiphilum (E.F. Smith) Snyder & Hansen, occurs locally in southern Nigeria. Sources of *Fusarium* wilt resistance include TVu's 109-2, 347, 984, 1000 and 1016-1 (Oyekan, 1975; 1976).

Other minor fungal pathogens in southern Nigeria include lamb's trial pod rot caused by *Choanephora infundibulifera* (Curry) Sacc. which frequently becomes established in insect damaged pods during cool wet weather; false leaf smut (*Protomycopsis phaseoli* Ramakrishman & Subraman) which appears to be widespread in Africa and India, and an angular pinkish leaf spot caused by *Aristastoma guttulosum Sutton*.

11.5 Bacterial diseases:

The bacterial diseases of cowpea are the least studied diseases of this crop in Nigeria. However, there are at least two important bacterial diseases on cowpea.

11.5.1 Bacterial pustule:

Bacterial pustule is a widespread disease of both cultivated and wild cowpeas in Nigeria, Tanzania and probably elsewhere in Africa. The symptoms begin as tiny dark water-soaked dots on the underside of the leaves.

On susceptible varieties the dots enlarge to become roughly circular spots 1-3mm diam., which when young appear as raised dark water-soaked pustules on the under surface of the leaf, and as dark brown necrotic spots on the upper surface. Older larger pustules become dry and sunken in the centre and water-soaked around the margin. These symptoms are similar to those described by Patel and Jindal (1972) for a bacterial leaf spot of mung bean in India except that in mung bean the raised part of the lesion occurs on the upper leaf surface.

The disease spreads rapidly in rainy weather and also has a high incidence in susceptible lines grown under overhead (sprinkler) irrigation. Heavily infected leaves turn yellow and abscise and susceptible lines such as Prima can lose most of their leaves before maturity due to this disease.

The causal agent is a *Xanthomonas* sp., which is similar to but distinct from *Xanthomonas vignicola* Burkholder, the causal agent of cowpea bacterial blight or canker.

The best possibility for control of bacterial pustule is the use of resistant varieties. Many immune lines have been identified in the IITA screening program and the inheritance of this resistance is under investigation. Preliminary results (IITA, 1976) indicate that two gene pairs are involved in resistance to bacterial pustule in cowpea and that the mechanism of resistance involves epitasis (gene B suppressing gene A), but this hypothesis requires confirmation.

11.5.2 Bacterial blight:

Bacterial blight can be damaging to susceptible varieties but is not as widespread and important in Nigeria as bacterial pustule. The primary symptoms

of this disease, caused by *Xanthomonas vignicola* Burkholder are tiny water soaked dots on the under surface of the leaf. The water-soaked dots remain small and the surrounding tissue becomes necrotic and develops a tan to orange colouration with a yellow halo. On heavily infected leaves the necrosis coalesces so that large areas of laminae are coloured tan to orange within which the individual dark spots of the initial infection points remain. The pathogen also infects the stems causing cracking (stem canker) and causes water soaking of pods from where the pathogen enters the seed. The disease spreads rapidly during heavy rains and also when the crop is grown with frequent overhead (sprinkler) irrigation.

Methods of control include the use of clean seed and the use of resistant varieties. Sherwin and Lefebvre (1951) in the U.S. and Patel and Jindal (1970) in India were able to identify resistant varieties, which include Brabham; Buff, Iron, Suwanne and Victor. Resistant lines have also been identified in greenhouse tests at IITA (1976).

11.6 Nematodes:

Cowpeas are attacked by 24 species of nematodes distributed among 15 genera: Fifteen of these 24 species of plant-parasitic nematodes have been found in Nigeria. The most destructive on local cowpea are three species of the root-knot nematode. The root-knot nematodes are also the most wide spread in Nigeria being found abundantly in all states. The reniform nematode has also been proved capable of reducing cowpea yields in Nigeria and is widely distributed. Both kinds of nematodes can cause yield reductions of

20 to 30 percent. The life cycles of the root-knot nematodes and the reniform nematode have been studied for Nigeria and are essentially the same as reported in the literature for other tropical countries (Caveness, 1973). Plant-parasitic nematodes reported attacking cowpea are listed below. Species marked with a star have been found in Nigeria (Caveness, 1973).

Belonolaimus gracilis
**Helicotylenchus cavenessi*
**Helicotylenchus psoudorobustus*
Hemicycliophora arenaria
Heterodera glycines
Heterodera schachtii
**Hoplolaimus seinhorsti*
**Meloidogyne arenaria*
Meloidogyne thamesi
Meloidogyne ethiopica
Meloidogyne hapla
**Meloidogyne incognita*
**Meloidogyne incognita acrita*
**Meloidogyne javanica*
**Peltamigratus nigeriensis*
**Pratylenchus brachyurus*
Pratylenchus vulnus
**Radopholus similis*
**Rotylenchulus reniformis*
**Scutellonema brady*s
**Scutellonema clathricaudatum*
Trichodorus christiei
**Xiphinema americanum*
**Xiphinema basiri*

The most important nematode affecting cowpeas in Nigeria is the root-knot nematode (*Meloidogyne incognita* (Rofoid & White) Chitwood) which can cause losses of up to 64%. Some cowpea lines have been screened for their reaction to *M. incognita* under controlled conditions at IITA and results have shown that TVu's 264-2, 401, 857 and 1560 possess high levels of resistance (Caveness, unpublished report 1957).

Amosu (1974) has also identified sources of resistance to *M. incognita* and Amosu and Franckkowiak (1974) have shown such resistance is governed by a single dominant factor.

About 110 other species of plant parasitic nematode occur in Nigeria but their economic importance is yet to be established.

11.7 Parasitic higher plants.

Two species of higher plants are parasites of cowpea in Nigeria where locally they can cause severe crop loss. The species involved are the yellow flowered *Alectra vogelii* Benth. and the pink to mauve flowered *Striga gesneriodes* (Willd.) Vatke. both are members of *Scrophulariaceae* (see Okonkwo and Nwoke, 1975; Rattray, 1932).

There is evidence that some grain legumes (e.g. mung beans, chick peas) may reduce the incidence of *Striga* spp. parasitising sorghum in mixed cropping (Ohlander, 1976 Ethiopian Pulse Trial Programme).

11.8 Conclusions.

In Nigeria the cowpea is subject to severe damage by a complex of viral, fungal and bacterial diseases, which represent a major constraint to increased on-farm production and to more intensified cropping. Certain diseases such as Septoria leaf spot and cowpea aphid borne mosaic appear to be more important in the savannah region but the majority of diseases are more severe in the forest region where the dry season is much shorter and where there are extended periods of heavy rains with continuously overcast skies. Although there are chemicals that can control some of the diseases, with the exception of seed dressing treatments they are unlikely to be technically or economically

viable at the peasant farmer level, particularly in the high rainfall regions. In addition, no adequate chemical control measures are known for some of the diseases. The use of host plant resistance offers the best solution to the huge disease complex. Intensive screening of the cowpea world germplasm collection at IITA has identified sources of resistance to several of the major diseases. The identified resistance represents a potential solution to many of the disease constraints on cowpea in Nigeria. However, a massive coordinated national effort between pathologists and breeders is necessary to determine the most stable resistance and to incorporate this resistance into varieties with acceptable seed quality. Finally, even with acceptable disease control only a part of the 'pest and disease' problem will have been solved. Before intensive cowpea production can be undertaken, particularly in the southern part of Nigeria an integrated pest and disease control programme is needed which incorporates and coordinates the results of the investigations of both the pathologists and the entomologists.

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CHAPTER TWELVE

SEED PRODUCTION AND DISTRIBUTION

12.1 Introduction.

The major objective of any seed production programme is to supply good quality seeds of high yielding varieties to farmers. Thus, the actual impact of plant breeding programmes on food production depends upon the quality and efficiency of seed distribution and its ready availability to farmers.

Good quality seeds ensure genetic purity of the variety, high germination capability, freedom from seed borne diseases, freedom from impurities and seeds of noxious weeds.

Different classes of seed.

There are four classes of seed recognised by seed certification agencies.

(i) Breeder seed. This refers to the small quantity of pure seed directly produced by the plant breeder or originating institution.

(ii) Foundation seed. This is the progeny of breeder seed. The genetic identity and purity of the variety is maintained in foundation seed. Production is carefully supervised or approved by representatives of an agricultural experiment station. Foundation seed is the source of all certified seed classes, either directly or through registered seed.

(iii) Registered seed. This is the direct increase from foundation seed. Registered seed maintains satisfactory genetic identity and purity of the variety for production of certified seed. Registered seed is used as the source of certified seed in some crops.

(iv) Certified seed. This is the progeny of foundation seed or registered seed. Its production is guaranteed by inspection and certification by an agency independent of seed production agencies.

Not all countries use exactly the same names to describe these stages. The number of seed multiplication stages necessary is determined by the quantities of seed required. Thus, seed multiplication refers to the extent of increase in seed quantity in one seed multiplication generation. For example if 20 kg of seed is planted this may result in a yield of 1000 kg of processed seed. This gives a multiplication ratio of 1:50. In the multiplication of seed of a particular variety it is important to know the distinguishing and agronomic characteristics.

12.2 How varieties are maintained.

In self-pollinated crops like the cowpea, the maintenance of varietal purity is not a serious problem provided the right class of seed is used and mechanical mixtures are avoided. By adequate roguing, avoidance of volunteers and by using approved source of seed for planting, the danger of varietal contamination is reduced.

Seed multiplication is an operation in which a combination of official, commercial, cooperative and private agencies are involved. Approved private farms under a certification scheme can produce certified seed for government at a premium price of say 15-20% above the current price. Supervision of these private farmers is the function of the seed quality agency independent of the seed production agencies.

The maintenance of a variety and the production of breeder seed are the responsibility of the breeder. The subsequent production of basic seed is often the combined responsibility of the breeder and the seed industry.

Seed quality is controlled by government agencies which inspect and certify the seed crop at various stages. Regulations on variety quality, seed quality and plant quarantine play a role in the breeding and distribution.

The extent to which new varieties are available in a country depends, on the one hand on the amount of breeding activity within that country and government regulations controlling the release of new varieties. Excessive bureacracy may cause delays in the introduction of new varieties. Unreasonable requirements for homogeneity, varietal purity, etc. may not only delay the introduction of a good variety but can even result in its rejection. Governments should take a pragmatic view and adapt their demands to the requirements of the farmers in their country.

12.3 Elements of seed production.

Production of high quality seeds requires a number of steps as described below.

(i) Use of genetically pure seeds of the given variety from a dependable source.

(ii) Seed should be multiplied on clean land that did not have another variety of the same crop the previous season. This prevents volunteer plants.

(iii) The field should be free of serious weeds common to the seed crop and free from seed which may get mixed up with crop seeds to pose problems of separation.

(iv) The variety should have proper isolation of specified distance from other varieties of the same species. Depending upon the varieties 3 to 4m between the different varieties is adequate.

(v) Proper cultural practices, fertilizer applications, insecticides and weed control have a great influence on both seed quality and quantity and the economics of seed production.

(vi) Field inspection is important. It involves identification of the variety, determination of varietal purity and recognition of diseases; noxious weeds and off-types. Through roguing of diseased plants and varietal mixtures should be done at the appropriate stages of crop growth. Roguing should be done at least three times first at pre-flowering stage, secondly at flowering stage and thirdly at maturity.

(vii) Harvesting must be done at the right maturity and moisture content to ensure good quality seeds.

In cowpeas the problem is not when to harvest but how often to harvest ripe pods to obtain high seed yield of high quality. Cowpea cultivars can be divided into two major groups (i) determinate cultivars that flower and produce pods within a short time, and (ii) indeterminate cultivars that flower and produce pods over a long period of time. Most cowpea cultivars belong to the latter category.

During a favourable, long growing season, indeterminate, day-length-insensitive cultivars generally out-yield determinate cultivars. But to obtain high yields, indeterminate cultivars should be harvested several times in contrast to one or two harvests for determinate cultivars.

(viii) Drying and threshing should be done timely and carefully to prevent damages and mechanical mixtures. Elsewhere once cowpea is harvested the pods have to be dried and in the savannah natural sun is used. The dry pods are

threshed often by beating the pods on a hard surface or by beating the pods enclosed in a jute sack with a stick. This is followed by winnowing to clean the seed. Threshing machines with cleaning facilities are vaailable but are generally not within the financial means of a traditional farmer.

Seeds are often treated with chemicals as a protection against seed-borne and soil-borne diseases. In treating the seed special care is needed to ensure uniform dressing of all seeds. In a warm and humid climate special care should be taken in packaging the seed for distribution. Where conditions of storage between time of delivery and time of sowing are unfavourable and especially where the atmosphere is humid, moisture-proof packaging may be desirable but in this case the seed should be subjected to extra drying to reduce moisture content.

(x) There should be a timely proper testing of seeds in the laboratory. Laboratory seed tests include verification of identity and varietal purity, in so far as this is possible. The next step is the determination of moisture content and analytical purity, the sample being separated with pure seed, seed from other crops, weed seeds and inert impurities. The pure seed is used for determination of germination and health.

When a seed lot has passed -through the control measures and has been found adequate, it can receive certification. Certain certificates issued by official seed testing stations are based on laboratory analyses only, and do not require field inspection. Many countries, however, have seed certification

schemes in which the entire seed production process is subject to supervision. Schemes of this kind can promote the availability of light quality seed of tested varieties. They also expedite the introduction of superior new varieties and improve the stability of existing varieties. Certified seed will automatically promote its own further use when the farmer discovers that certified seed generally yields more than seed retained from his harvest.

12.4 Quarantine.

Quarantine Services are essential to watch over the imports of seed from other countries and guard against the introduction of exotic seed-born diseases. A judicious policy would aim at more production of all seed required for the major crops, but sometimes it may be necessary to import some.

12.5 Extension services.

The extension services have important roles to play in obtaining the best possible utilization of high quality seeds. Particularly in the early stages of development, farmers need to be persuaded of the advantages of improved seeds. This can be carried out with the help of seed technologists and agronomists.

12.6 Purification and release of a variety.

A line that has been judged suitable for release is purified to remove off-types that can arise by several means.

(i) Seeds from another line that were mixed during threshing.

(ii) Natural crossing may occur between lines grown adjacent to one another and the hybrid and its offspring would represent off types.

(iii) A line may have been heterozygous for a gene when it was selected for testing.

(iv) Natural genetic changes (mutation) can cause visible changes in plant or seed characteristics.

A procedure for purifying and increasing a variety is outlined below.

A Scheme for purification and release of a line.

Season	Procedure
1	Harvest several numbered individual plants separately
2	Plant individual plant progenies separately
	Discard rows or off type plants showing segregation
	Bulk seed of similar type
3	Plant pedigree seed in bulk
	Rogue off-type plants if any
	Harvest breeder seed
4	Plant breeder seed
	Rogue off-type plants
	Harvest foundation seed
5	Plant foundation seed
	Harvest registered seed
6	Plant registered seed
	Harvest certified seed

12.7 How a new variety reaches the farmer.

1. A variety is ready for release and distribution when it has been proved to be distinctly superior to existing commercial varieties in at least one or more characteristics, and satisfactory in all other important respects. The superiority is often proved in tests carefully planned and conducted in comparison with standard commercial varieties in the orginating country and in regional tests which provide reliable information on the range of the variety adaptation.

2. The decision for release is made by the breeder in consultation with appointed boards of review. The breeder seed is then generally turned over to some agency responsible for making the foundation seed increase.

3. The organisation making the increase of foundation seed varies in different countries. In some countries a foundation seed is developed within the agricultural experiment station. In other countries foundation seed is produced by private organisations closely associated with experimental stations.

4. At least one year before distribution by orginating station, each experimental station in the region of adaptation of the new variety is normally informed of plans to release a variety and seed is supplied to them in quantities to permit field plot testing at one or more locations.

5. The variety is named at the originating station, in consultation with representatives for other national experiment stations.

6. First distribution of foundatinn seed is usually made to selected farmers who by past experience have proved their ability to produce registered

and certified seed with a high standard of quality.

7. Distribution of certified seed is made to certified growers throughout the country. The certified seed harvested from this increase then usually becomes available without restriction to any grower within the state in so far as the seed supplies are available.