INTERCROPPING WITH SWEET POTATO

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CERTIFICATE

This is to certify that the work recorded in the thesis entitled 'Intercropping with sweet potato' submitted by Shri Ajit Prasad Patra for the award of the Degree of Doctor of Philosophy in Agronomy of the Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, is the faithful and bonafide research work carried out under my personal guidance and supervision. The results of the investigation reported in the thesis have not so far been submitted for any other Degree or Diploma. The assistance, help and source of informations, as have been availed of during the course of investigation, have been duly acknowledged.

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(B. N. Chatterjee)

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LIST OF ABBREVIATIONS

A	=	Aggressivity
A_s	=	Aggressivity of soybean (in combination with sweet potato)
A_{sp}	=	Aggressivity of sweet potato (in combination with soybean or maize or pigeonpea)
CR	=	Competitive Ratio
CR_s	=	Competitive Ratio of soybean (in combination with sweet potato)
CR_{sp}	=	Competitive Ratio of sweet potato (in combination with soybean or maize or pigeonpea)
DAS	=	Days after sowing of grain crops (soybean, maize and pigeonpea)
LER	=	Land Equivalent Ratio
M	=	Maize
P	=	Pigeonpea
S	=	Soybean
SP	=	Sweet potato

ABSTRACT

A number of field experiments were conducted, to analyse the growth and productivity of crops, (i) in one series, on the intercropping of soybean with sweet potato under different spatial arrangements and timings of planting of sweet potato, and (ii) in another series, on the intercropping of sweet potato at a fixed spatial arrangement but with crops of different growth habits (maize, soybean and pigeonpea).

Bio-mass production per unit area in soybean (cv. Bragg) was reduced more (up to 60 %) when intercropped with sweet potato in 1 : 1 rows 60 cm apart under simultaneous establishment, mainly because of decreased plant population. The reduction was less (18 to 32 %) under the other three spatial arrangements (2S : 1SP, 1 : 1 rows 30 cm apart and 2 : 2 alternate paired rows). The growth of maize (cv. Diara Composite) and pigeonpea (cv. AS-8) was reduced due to intercropping (in 1 : 1 rows 60 cm apart) by 12 to 17 % and 18 to 25 %, respectively only under simultaneous establishment. Under simultaneously established maize / sweet potato, followed by soybean / sweet potato intercroppings (in 1 : 1 rows 60 cm apart), sweet potato accumulated dry matter more efficiently than under sole cropping. When pigeonpea was intercropped, the growth of sweet potato was drastically reduced.

Local variety of sweet potato had much lower yield potentiality than those of cv. H-268 and Pusa Safed. Simultaneously established soybean / sweet potato intercropping under 1 : 1 rows

60 cm apart arrangement produced tuber yields (330 to 448 q / ha) similar to under sole croppings of sweet potato (cv. H-268 and Pusa Safed) and 907 to 1450 kg / ha of soybean grain yields (35 to 54 % of sole crop yields), which was an additional advantage over the equivalent sole crop yields of sweet potato. Simultaneously established soybean / sweet potato (cv. H-268) intercroppings under 1 : 1 alternate rows 30 cm apart, 2S : 1SP and 2 : 2 alternate paired rows arrangements recorded 149 to 255, 165 to 232 and 221 to 273 q / ha of tuber yields, respectively, and 1561 to 1979 kg / ha of soybean grain yields. Simultaneously established maize / sweet potato intercroppings (plant population of intercrops equivalent to those under sole croppings) recorded 398 to 465 q / ha of tuber yields (11 to 25 % more than under sole croppings of cv. H-268 and Pusa Safed) and 3008 to 3765 kg / ha of maize grain yields (64 to 89 % of sole crop yields), which was an added advantage over the equivalent or slightly higher sweet potato yields under sole croppings. Pigeonpea / sweet potato intercroppings produced only 2 to 32 % tuber yields and 71 to 116 % pigeonpea grain yields as compared to respective sole crop yields. The total productivity of grains and tubers under intercroppings increased as the differences in the maturity periods of the two component crops widened (r = 0.95 to 0.99).

Aggressivity of sweet potato (cv. H-268 and Pusa Safed) was maximum under soybean / sweet potato intercropping (A_{sp} = 1.17 to 1.43), followed by maize / sweet potato intercropping (A_{sp} = 0.65 to 1.23), under simultaneous establishment in 1 : 1 alternate rows 60 cm apart arrangement. When pigeonpea was

intercropped, sweet potato was dominated by it (A_{sp} ranging from -0.80 to -2.28).

In simultaneously established soybean / sweet potato (cv. H-268 and Pusa Safed) intercroppings, the LER values for the combined intercrop yields of soybean (0.35 to 0.46) and sweet potato (1.05 to 1.11) ranged from 1.42 to 1.55, under 1 : 1 alternate rows 60 cm apart arrangement, where competition was in favour of sweet potato. Under simultaneous establishment, other spatial arrangements recorded total LER values of 1.16 to 1.70 mainly due to high LER values of soybean (0.64 to 0.85). Simultaneously established maize / sweet potato (high-yielding varieties) intercroppings recorded LER values of maize 0.64 to 0.89 and of sweet potato 1.11 to 1.25 and thus produced 85 to 110 % yield advantages, when the competition was in favour of sweet potato. Pigeonpea / sweet potato intercroppings recorded total LER values of 1.02 to 1.18; the slight yield advantage was mainly due to high LER values of pigeonpea (0.71 to 1.16).

Monetary advantage (price of produce only) and calorie value of the total produce per hectare were Rs.20,095/- to Rs.22,704/- and 64.41 to 72.07 million calorie under maize / sweet potato, and Rs.12,573/- to Rs.16,340/- and 47.04 to 61.93 million calorie under soybean / sweet potato intercroppings, respectively, when high-yielding varieties of sweet potato were established simultaneously with the component crops in 1 : 1 alternate rows 60 cm apart arrangement. Pigeonpea / sweet potato intercroppings recorded monetary disadvantages.

It was concluded that the long duration (200 days) crop of sweet potato (cv. H-268 and Pusa Safed), which has high yield potentiality in light soils, can profitably grow with short duration crops of maize (cv. Diara Composite - 95 days) and soybean (cv. Bragg - 115 days) in alternate rows 60 cm apart, established simultaneously. The intercroppings increased bio-mass productivity, economic yield, Land Equivalent Ratio, monetary return and calorific values of the produce as compared to the sole cropping of sweet potato; this was because of the better utilisation of physical resources, more particularly of light under intercropping. Interplanting of sweet potato, at 45 days after sowing (after earthing up of maize) in between the two rows of maize (120 cm apart) also showed appreciable advantage.

Pigeonpea / Sweet potato intercropping recorded unfavourable returns and proved [illegible]

1. INTRODUCTION

With the advent of high-yielding varieties and improved technology, the total production of cereal crops like, rice, maize, wheat etc. has been increased throughout the world during the recent years. In the Asian countries, until recently, most of the agricultural research has been aimed to increase the production of cereal crops, particularly rice, since these provide staple food. At present a number of countries have either achieved or nearly achieved self-sufficiency in these crops, and efforts are now being made to increase the production of other food crops.

Quite a large number of people in the developing countries is still under-nourished from the calorie and protein point of view. The protein deficiency in the daily diet is largely due to high cost of food that supplies protein. In view of the high cost and reduced supply of the conventional sources of animal protein, the emphasis is being given to increase the production of grain legumes, an alternative source of cheap protein. Among the legumes, soybean occupies a prominent position for its high percentage (43.2 %) as well as the quality of protein. The production potentiality of the soybean crop is also appreciable, and 2.0 - 2.5 t / ha of grain yield has been obtained in different parts of India (Singh and Balasubramanian, 1979). Pigeonpea is another important grain legume crop in India. It has comparatively higher production potentiality than some other legumes like blackgram and greengram.

Among the grain crops, maize has the highest production potentiality, 4.0 - 5.0 t / ha of grain yield has often been produced by the Indian farmers (Singh and Balasubramanian, 1979). Maize, a C_4 crop, has the characteristic shape, arrangement and disposition of leaves, which enables efficient utilisation of solar radiation. It also allows some amount of radiation to transmit through the leaves at the ground level and provides scope for the growth of another low-growing crop as an intercrop.

Sweet potato (Ipomoea batatas L. Lam.) has much higher yield potentiality than the grain crops. It is able to adapt itself to a wide range of growing conditions and is also said to be drought-tolerant. It is also used as an important vegetable, being a staple food in a number of countries. Besides, it is a useful crop for stock feed and for the provision of industrial raw materials. The tubers possess high nutritive value. Sweet potato has comparatively lower calorific value (132 cal / 100 g) than the grain crops, like soybean, maize and pigeonpea which have high calorific values (335, 360 and 343 cal / 100 g of edible portion, respectively; Aykroyd and Doughty, 1973). But due to much higher production per unit area of sweet potato than that of grain crops, calorie production per unit area is much higher in sweet potato than in other grain crops.

Sweet potato requires 4 - 6 months period, free from frost and even from chilly weather. An average temperature of 24°C favours root formation and 22°C favours root enlargement (Wang, 1975). Chatterjee and Mandal (1975) have reported 20 - 30 t / ha

of tuber yield when planted during August to October and harvested in March - April. Tuber bulking has been reported to be favoured at mean temperature of 23 - 27 °C during mid-October to mid-November and mid-February to mid-March.

Soybean crop is sown during mid-June to mid-July and harvested in November. Sequential cropping of soybean and sweet potato is not conducive to high production as planting of sweet potato will be much delayed if it is to be planted after harvesting of soybean. Growing of these crops on the same land is possible, only when at least part of the growing period of them are overlapped.

The efficiency of agricultural production depends on the maximum utilisation of sunshine for photosynthesis by the crop plants. In terms of light utilisation, dry matter yield is at an optimum when nearly all of the incoming solar radiation is intercepted. The principle of intercropping is in line with ecological systems in nature, where the niches created by larger species are successfully utilised by the ecologically smaller ones. This progressive accommodation ensures a high and efficient utilisation of the energy in the ecosphere and leads to maximum production. To achieve this, it is necessary to find out the ways and means for the efficient utilisation of solar radiation. Advantages in intercropping through better use of growth resources are mainly due to temporal and also due to spatial complementarity (Willey, 1979).

With the above considerations and in view of increasing production, the present investigation was undertaken. Here, soybean

was intercropped with sweet potato under different spatial arrangements and dates of planting of sweet potato, in one series. In another series, for evaluating comparative suitability of soybean as a component crop to be grown with sweet potato, two other crops, maize and pigeonpea, having different growth habits, stature and duration, were also included, and they were intercropped with sweet potato at a fixed spatial arrangement under relayed planting of sweet potato.

The objectives of the present investigation were :

(i) To analyse the growth and yield of crops under different cropping systems and to find out the reasons of the yield variations in the intercrops as compared to the sole crops; and

(ii) To agronomically appraise productivity in terms of land equivalence and competitive ability of different crops under different systems of cropping.

2. REVIEW OF LITERATURE

Intercropping is defined as the growing of two or more crops simultaneously on the same area of land. It is not a new practice, rather it is a primitive one from which sole cropping has come up as a natural and inevitable consequence of agricultural development. The importance of intercropping has long been recognised in India (Aiyer, 1949) and in other tropical countries as well. Recently, intercropping has become a subject of agricultural research and a good amount of scientific informations have been accumulated (Willey, 1979) since the review of works on intercropping done by Aiyer (1949) and Raheja (1953, 1971, 1973).

2.1 Advantages of intercropping

Advantages of intercropping can be in the forms of (i) greater stability of yield over different seasons (Norman, 1972; Jodha, 1976; Rao and Willey, 1980) and (ii) higher yield in a given season (Cordero, 1978; Ahmed and Gunasena, 1979; Kalra and Gangwar, 1980).

2.2 Causes of yield advantages under intercropping

A major cause of yield advantages is the better use of growth resources. The yield advantages occur because the component crops differ in their use of growth resources, and in combination they can 'complement' each other and so make better overall use of growth resources than when grown separately. The 'complementarity' may be 'temporal', when the growth patterns of component crop differ in time so that the crops make their major demands on resources at

different times. By temporal use of resources yield advantages have been obtained with crops having marked difference in maturity period (Willey and Osiru, 1972; IRRI, 1974, 1975; Krantz et al., 1976). 'Spatial' complementarity may also be possible, e.g., a combined leaf canopy may make better spatial use of light, or a combined root system may make better spatial use of nutrients and / or water.

The growth resources to be better used for producing yield advantages are light, nutrients and water. Yield advantages have been obtained through better temporal use of light due to better distribution of leaf area over time (IRRI, 1975; Kundu and Chatterjee, 1982) or due to longer leaf area duration (Lakhani, 1976). Yield advantages with better spatial use of light have to be obtained through more efficient use of light rather than greater light interception (Willey, 1979). Better spatial use of light can be made through greater vertical distribution of leaf canopy (Osiru, 1974) or through use of crops having different inherent responses to light, like a tall C_4 and a short C_3 crop (Crookston and Kent, 1976) or through a 'multi-story' cropping, where crops ranging from tall trees to low-growing annuals form different canopy layers (Nelliat et al., 1974). Better use of nutrients can be possible due to differences in rooting patterns, which may also occur due to 'mutual avoidance' of different root systems (Baldwin et al., 1972; Trenbath, 1974; Lakhani, 1976). Greater uptake of different nutrients (Dalal, 1974; Lakhani, 1976) and better use of water (Kassam, 1973; Lakhani, 1976; Natarajan and Willey, 1980) by intercropping are also possible. In legume / non-legume

intercroppings, increase in yield of non-legume crops has been reported by a number of workers (Kassam, 1972; Finlay, 1974; IARI, 1976; Singh, 1977). Efficiency of N-fixation may increase under intercropping, e.g., in pigeonpea grown with sorghum (Willey, 1979) and in soybean grown with maize (Thompson, 1977).

Another most important cause is the possibility of exercising better control of weeds (Litsinger and Moody, 1975; Rao and Setty, 1977) and pest and diseases (Baker and Norman, 1975; Crookston and Kent, 1976; Raheja, 1977); although there are instances of poor control (Osiru, 1974; Pinchinat et al., 1975) as well. In certain situations there are still some other possible causes of yield advantages, e.g., one crop may provide physical support for another (Aiyer, 1949), one may provide shelter for another (Rathke and Hegstrom, 1975) or better control of erosion due to more continuous leaf canopy (Siddoway and Bonnett, 1975).

2.3 Disadvantages of intercropping

Disadvantages of intercropping are in the forms of (i) lowering of yields due to adverse competitive effects (Donald, 1946; Harper, 1961), (ii) allelopathic effects (Rice, 1974) and (iii) difficulties in practical management.

2.4 Criteria for assessing yield advantages

Advantages from intercropping can be analysed into three different situations (Willey, 1979).

(i) Where intercropping must give full yield of a 'main' crop and some yield of a second crop.

(ii) Where the combined intercrop yield must exceed the higher sole crop yield. This has been traditionally used for assessing yield advantages in grassland mixtures (Donald, 1963) and recently in other situations also (Trenbath, 1974).

(iii) Where the combined intercrop yield must exceed a combined sole crop yield.

2.5 Competitive relationships

In 'replacement series' three situations of competition have been recognised, viz. (i) 'mutual inhibition', where actual yield of each component crop is less than expected (Donald, 1946; Harper, 1961; Bhattacharyya, 1979); (ii) 'mutual cooperation', where actual yield of each component is greater than expected (Bhattacharyya, 1979); and (iii) 'compensation', which is the much commonest situation, where one species yields less than expected and the other more. In this situation, competitive abilities of two species differ, and the more and less competitive species in a mixture are termed as 'dominant' and 'dominated', respectively (Huxley and Maingu, 1978).

2.6 Competition functions

In assessing the yield advantages, a number of 'competition functions' have been proposed to describe competitive relationships.

(i) 'Relative Crowding Coefficient' has been proposed by de Wit (1960) and examined in detail by Hall (1974a, 1974b). This coefficient (k) of a species is a measure of whether that species has produced more, or less, yield than expected. A coefficient

value less than, equal to or greater than one indicates less, the same or more yield than expected, respectively. The component crop with higher coefficient is a dominant one. The product of the coefficients (K) indicates whether there is yield advantage or not.

(ii) 'Competition Index' has been suggested by Donald (1963). Two 'equivalence factors' are calculated for each crop. For species 'a' the equivalence factor is the number of plants of species 'a' which is equally competitive to one plant of species 'b'. A crop having equivalence factor of less than one indicates to be more competitive. The product of two equivalence factors is the 'Competition Index'; when it is less than one the intercropping is advantageous.

(iii) 'Aggressivity' (A) is a measure of how much the relative yield increase in species 'a' is greater than that for species 'b' (Mc Gilchrist, 1965). When this value is zero, it indicates the equal competition. The value of dominant species will be positive and that of the dominated negative.

(iv) Since the above mentioned competition functions have some drawbacks and limitations they cannot be applied widely. Willey (1979) has concluded that the most generally useful single index for expressing the yield advantage is probably the 'Land Equivalent Ratio' (LER), which is defined as the relative land area under sole crops which is required to produce the yields achieved under intercropping. It gives a measure of yield advantage. Similar terms 'Relative Yields', for component crops, and 'Relative

Yield Total' (RYT) were used for many years in competition studies (de Wit and van den Bergh, 1965).

The actual level of intercropping advantage, for any given combination and proportions of the component crops producing this, can be shown by graphical representation, where the LER values of two component crops are plotted on the two axes and the total LER values are shown by the diagonal lines which join these axes (Willey, 1979).

(v) 'Effective LER' has been proposed by Mead and Willey (1980) to evaluate situations where the yield proportions achieved in intercropping are different from those that might be required by a farmer. This index has been emphasised to indicate the proportions of crops likely to give biggest yield advantage.

(vi) 'Monetary advantage' by using LER values, can also be determined (Willey, 1979) and this gives the absolute values of the genuine yield advantage.

(vii) Chetty and Rao (1979) have suggested the use of 'I_3' index which takes into consideration the ratios of prices of concerned crops but does not consider the cost of cultivation of the said crops.

(viii) Jain and Rao (1980) have proposed the use of 'Relative Net Return' (RNR) index, which takes into consideration the cost of cultivation.

(ix) 'Competitive Ratio' (CR), proposed by Willey and Rao (1980), indicates the number of times by which one component crop

is more competitive than the other. It has been suggested to be useful in comparing different crops and identifying the associated plant characters in respect of competitive ability and in determining the most advantageous competitive balance between the components.

2.7 Production potentiality of the experimental crops under sole and intercropping systems

2.7.1 Soybean

A sole crop yield of 2.0 - 2.5 t / ha of soybean cv. Bragg was obtained from different parts of India (Singh and Balasubramanian, 1979). Soybean yield decreased when grown as intercrop with other crops as compared to under sole cropping. In maize / soybean intercroppings, maize crop was not affected and produced yield comparable to sole crop yield (Singh and Guleria, 1979; Singh and Chand, 1980) or even more (Reddy and Chatterjee, 1976a; Gangwar and Kalra, 1979; Jagannathan et al., 1979; Galal et al., 1980; Searle et al., 1981) and the soybean yield was reduced. Thus a 'full' maize yield and some extra yield of soybean were obtained. The same criteria was fulfilled when soybean was grown with winter wheat and spring oats. A tall indeterminate soybean cv. appeared to withstand competition better than a short determinate cv. (Chan et al., 1980). Reduction in soybean yield was also reported when intercropped with sugarcane (Chandra, 1978).

Intercropping, although reduced soybean yields, produced total yield of both species greater than in monoculture (Reddy and Chatterjee, 1973b; Ahmed and Gunasena, 1979; Saxena and Yadav, 1979; Galal et al., 1980; Mohta and De, 1980). Under maize /

soybean intercroppings, the mean LER values varied from 1.22 to 1.48 (Galal et al., 1980; Hiebsch and Mc Collum, 1980; Mohta and De, 1980). Thus intercropping gave better gross return than sole cropping (Chandra, 1978; Ahmed and Gunasena, 1979). Crookston and Hill (1979), however, reported that Minnesota land use efficiency was not improved by intercropping maize and soybeans in a variety of management combinations.

Reddy and Chatterjee (1976a) reported that leaf area duration (flowering to maturity) of sole and intercrops was significantly correlated with yields. The competitive indices showed advantages in intercropping. The leaf area duration of maize, in maize / soybean mixture, was twice as long as in the monoculture and the productivity of this intercropping was 20 - 40 % greater than when crops were grown alone (Cordero, 1978). Reddy and Chatterjee (1973b) reported that intercropping of maize and soybean exploited the natural radiations better than sole crops for productive purposes. In maize / soybean intercropping, maize was removed from the soybeans at flowering, pod formation, seed formation or was left up to soybean maturity. It was found that delaying removal of maize from the intercrops decreased soybean yields from 75 to 50 % of their monoculture yield. Gain in weight by intercropped soybeans during their reproductive stage was linearly related to the percent of incoming photosynthetically active radiation absorbed over the entire range from 28 to 96 % (Hiebsch and Mc Collum, 1980). Soybeans intercropped between wheat and oat rows, 41 and 61 cm apart, yielded between 7 and 93 % of monoculture soybeans grown at similar row spacings (Chan et al., 1980). Undersowing of rice into soybean (sown by the end of January) in June, appeared suitable, as there

was no effect on yield of both the crops and there was 20 days advantage over sole croppings of both the crops (Reddy and Chatterjee, 1976b). Thus, soybean yields were reduced under intercropping, partly due to reduced number of rows and partly due to shading effect for which light interception by soybean was reduced as compared to under sole cropping.

Reddy and Chatterjee (1976a) reported that intercropping of soybean and maize in 1 : 1 ratio gave higher yields than the sole crops of maize or soybean at all levels of nitrogen, the yields of soybean being appreciably reduced particularly at high doses of nitrogen due to competition with maize. Soybean grown with maize in 2 : 1 or 3 : 1 ratio yielded more than in 1 : 1 ratio. The number of pods per plant and the test weight of soybean were reduced when it competed with maize. When soybean (cv. Bragg) was grown with sorghum (cv. Swarna) in alternate rows 45 cm apart, the intercropping outyielded sole crops (Reddy and Chatterjee, 1974). Jagannathan et al. (1979) obtained good results from maize/ soybean intercropping in both 1 : 2 and 2 : 1 ratios; the 1 : 2 ratio increased the protein content of maize grain. Mohta and De (1980) reported that maize / soybean intercropping under 1 : 2 arrangements with 40 cm apart rows and sorghum / soybean under 1 : 1 arrangement with 45 cm apart rows were best.

At 40 kg N / ha, intercropping maize with soybean gave 19.5 % more grain yield than taking it as a pure crop. When the option to use adequate fertilizer N does not exist, as is invariably the case with the average Indian farmer, intercropping maize with legumes, such as soybean, is a logical way out (Nair et al., 1979).

In intercropping of maize with soybean and other legumes, increasing the N rates from 0 to 120 kg / ha increased total yields of the mixed stands and also of sole maize. N content and uptake in maize plants were increased with applied N, but were not affected by intercrops (Chand, 1978). Maize / soybean intercroppings were reported to leave sufficient residual fertility to increase significantly yield of following wheat crop, given no fertilizer (Nair et al., 1979; Searle et al., 1981).

2.7.2 Maize

Under sole cropping, the farmers often produced 4 - 5 t / ha of grain yield of maize with high-yielding varieties, in India (Singh and Balasubramanian, 1979). Under intercropping situations, better use of growth resources were reported, and when legumes were intercropped maize yields were found to be even higher than in sole crop. Under dry land agriculture, maize, when intercropped with blackgram, produced grain yield of 2.49 t / ha with an additional blackgram seed yield of 0.33 t / ha, compared with 1.81 - 2.16 t / ha in sole crop (Rathore et al., 1980). Similarly, Kalra and Gangwar (1980) obtained higher yield of maize (1.57 - 1.97 t / ha) grown in association with legumes, compared with yield (1.52 t / ha) in pure stand and an extra seed yield of legumes (0.36 - 1.01 t / ha) under rainfed condition. Similar yield advantages were reported by Gangwar and Kalra (1979) when maize was intercropped with blackgram, greengram, groundnut, soybean and cowpea under rainfed condition. The advantages of maize / soybean intercropping have been discussed in the earlier section. In intercroppings of maize / cowpea, relative bio-mass yield (compared

with monoculture yield) of maize was always higher than expected at 7, 9, 11 and 18 weeks after sowing; maize had no negative interference from cowpea. Relative bio-mass yield of cowpea was lower than expected at 11 and 16 weeks after sowing (Chang and Shibles, 1980), implying dominance of maize particularly under high levels of nitrogen and phosphorus. Application of N to maize / legume intercropping appeared inhibitory to N-fixation, because of (i) direct effect of increased soil N, and (ii) indirect effect of stimulation of maize growth and shading of intercropped legumes (Reddy and Chatterjee, 1973a; Syariffuddin et al., 1974; Ahmed and Gunasena, 1979; Searle et al., 1981). Under certain situations of intercropping, maize yields were equal to those under sole croppings (Ahmed and Gunasena, 1979; Aidar and Vieira, 1979; Singh and Guleria, 1979; Searle et al., 1981). Thus, farmer's primary objective of maintaining a 'full' maize yield was achieved in intercroppings with maize.

In the intercropping trials, where field bean (Phaseolus vulgaris) was sown in between the maize rows, when the maize was beginning to dry, Aidar and Vieira (1979) obtained increase in bean yields with the decrease in maize population in one trial; while in another trial, there was no effect of plant population. When groundnut, pigeonpea and sweet potato were intercropped with maize, the maize grain yields increased with the increase in plant populations of maize (Akhanda, 1979). In maize / blackgram intercropping, Khera et al. (1979) obtained higher seed yield of blackgram intercropped in dwarf maize cv. J-605 with erect leaves than when intercropped in the tall and leafy cv. Vijay. Similarly,

Akhanda (1979) also reported higher forage and / or seed yields of the intercrops (groundnut, pigeonpea and sweet potato) with earlier maturing maize cv. at the lowest plant population.

The yield advantages, in maize intercropping, were obtained due to more effective utilisation of radiation, temperature and water, and higher dry matter yield, LAI, LAI duration and CGR than under sequential cropping as was observed in relay intercropping of maize and wheat (Lin et al., 1981). In intercroppings of maize with other crops, when there were marked differences in the maturity periods of the two component crops, substantial yield advantages were obtained due to better temporal use of growth resources, e.g., 85 day beans / 120 day maize produced 38 % yield advantages (Willey and Osiru, 1972), 85 day maize / 120 day groundnut produced 20 - 60 % yield advantages (IRRI, 1974), 90 day maize / 160 day rice produced 30 - 40 % yield advantages (IRRI, 1975). In an experiment on the intercropping of soybean, rice, greengram and maize with turmeric, it was observed (Kundu and Chatterjee, 1982) that wider the gaps between the harvests of two companion crops lesser were the reductions in yield of turmeric (r = 0.81 to 0.88). The advantages occurred due to differences in both maturity and crop type. Better temporal use of light was possible in intercropping due to longer leaf area duration than in monoculture (Cordero, 1978). In some cases, as in maize / rice intercropping (IRRI, 1975), although sole rice had a much higher leaf area duration than the intercrop, the latter was thought to derive its high yielding advantage from the much better distribution of its leaf area over time. Kassam (1973) suggested that an early intercrop, such as millet if grown

with maize, would help to utilise the surplus water available at the early stage of maize growth at Nigeria, and thus more efficient use of water was possible. The nitrogen contribution of intercrop legumes to maize was reported to be 40 kg / ha from groundnuts and 25 kg / ha from greengram (IARI, 1976). Similar but smaller advantages were also reported with maize / groundnut intercropping in northern Nigeria (Kassam, 1972), maize / soybean in East Africa (Finlay, 1974), maize / beans in Colombia (Centro International de Agricultura Tropical, 1974) and maize / cowpea in Nigeria (Wien and Nangju, 1976). Regarding the genuine intercropping advantage, an apparent increase in nodule number and weight was reported in soybean when it was grown with maize (Thompson, 1977). Agboola and Fayemi (1972) examined both current and residual benefits of legume intercrops, and showed that when maize was intercropped with greengram, there was a bigger current transfer of nitrogen than with cowpea; but the residual effects were opposite, and cowpea had greater effect on the following maize crop than greengram.

2.7.3 Pigeonpea

As a sole crop, pigeonpea produced seed yield of 2.00 t / ha, and when intercropped with greengram and blackgram, it produced 1.96 and 1.98 t / ha, respectively; with extra seed yield of 0.98 and 0.88 t / ha of greengram and blackgram, respectively (IARI, 1976). Intercropping of blackgram, greengram (Giri and De, 1978; Singh et al., 1979), cowpea and soybean in between 75 cm apart pigeonpea rows had no adverse effect on seed yields of pigeonpea, and increased the total seed yields (Saxena et al., 1977; Saxena and Yadav, 1979); the intercropped legumes gave additional seed

yields of 0.42 - 0.79 t / ha (Saxena et al., 1977). Umrani and Pharande (1979) reported that pigeonpea yield decreased only slightly under intercropping (0.91 t / ha) as compared to under sole cropping (1.07 t / ha), when grown with pearl millet (1.57 t / ha), and recorded LER value of 1.77 and higher money return. On black soil of semi-arid tropics (ICRISAT, 1976), intercropping of a rapid-establishing, early-maturing and upright Setaria with a spreading, slow-establishing pigeonpea (6 months) was reported to be most favourable, where sole and intercrop yields of pigeonpea (2.5 t / ha) and Setaria (3.3 t / ha) were same. In the pigeonpea/ pearl millet intercropping system, pearl millet yield was not reduced, whereas pigeonpea yield was reduced by 22 % and there was an yield advantage of 83 % . In maize / pigeonpea intercropping, Yadav (1981) obtained mean maize grain yields and pigeonpea seed yields of 2.9 - 3.5 t and 0.7 - 1.7 t / ha in pure stands and 2.8 - 3.3 t and 0.3 - 0.5 t / ha in intercrops, respectively.

In sorghum (82 days) / pigeonpea (173 days) intercropping, a 'full' sorghum yield was achieved with plant density of intercropped sorghum equivalent to the sole crop optimum and the pigeonpea seed yields were up to 73 % of the sole pigeonpea. The optimum density for intercrop pigeonpea was considerably higher than sole crop optimum (Natarajan and Willey, 1980). Hegde and Saraf (1978) reported that intercropping of pigeonpea with some other legumes intercepted more light than sole pigeonpea at early stage; at 50 DAS the differences were narrowed, and when intercrops were harvested the intercrop treatments intercepted less light than sole pigeonpea. Phosphorus helped in better interception of light during later stages through its effect on canopy development.

Natarajan and Willey (1980) also reported of very poor light interception by remaining pigeonpea, after sorghum harvest in sorghum / pigeonpea intercropping and suggested that pigeonpea yield could be increased by higher plant population density and better plant distribution. Thus, intercropping of short duration crops with pigeonpea offered scope for better 'temporal' use of growth resources and produced yield advantages appreciably. Better 'spatial' use of light might also be possible in intercroppings of C_4 crops like maize or sorghum with C_3 crop pigeonpea. Sivakumar and Virmani (1980) reported of highest efficiency of dry matter production for the maize / pigeonpea intercrop, followed by sole maize and sole pigeonpea, proving the utility of such intercrops in making better use of growth resources in the semi-arid tropics.

From sorghum / pigeonpea experiments in semi-arid tropics, it was reported (ICRISAT, 1980) that on the Vertisol, where the sorghum growth was very good and the pigeonpea growth very suppressed, changing from 2 : 1 to 1 : 1 arrangement produced some overall benefit by increasing pigeonpea yield (from 54 to 67 %) without reducing sorghum yield (LER = 1.61) on the other hand, on Alfisol, where sorghum growth was poor and pigeonpea growth relatively better, changing to 1 : 1 row arrangement reduced sorghum yield (from 72 to 60 %) with little extra (from 71 to 76 %) pigeonpea yield (LER = 1.36). It was reported from ICRISAT (1977) that the three crop combination pigeonpea (184 days) / groundnut (134 days) / <u>Setaria</u> (90 days) gave larger advantages than the two-crop combination on Vertisol, suggesting that the different maturity periods of the three crops allowed some complementarity in terms of the

use of growth resources over time. However, on Alfisol, the three-crop combinations gave smaller advantages than did the two-crop combinations due to dry period during September. It was suggested that three-crop intercropping might be beneficial only if there was sufficient moisture to support all the three crops. Intercroppings were reported (ICRISAT, 1978) to have a potential for better use of moisture when compared with sole cropping, presumably because of complementary rooting patterns. This potential would produce a yield advantage when moisture was limiting, but not so when it was in adequate supply.

Intercropping of blackgram, greengram, cowpea, soybean or sunflower with an early-maturing pigeonpea cv. Type-21 (160 days) had no adverse effect on pigeonpea seed yields. But intercropping of these crops with an extra early-maturing cv. (130 days) was not profitable (Saxena et al., 1977), indicating the better 'temporal' use of resources when there were marked differences in maturity periods of component crops. At ICRISAT (1976), in sorghum / pigeonpea intercropping, a spreading pigeonpea cv. ST-1 (180 days) had the ability to utilize the wider (150 cm) row spacing late in the season and allowed more space for intercrops to utilise the environment early in the season,and thus increased the potential for total production of the intercropping system.

Far greater weed yields were reported (ICRISAT, 1976) in sole crop of pigeonpea as compared to in sorghum / pigeonpea intercropping. Thus the intercropping system increased total crop production and decreased the cost of weed management.

In maize / pigeonpea intercropping, pigeonpea increased soil N content, but as an intercrop it did not increase maize yield at any rate of N (Yadav, 1981). Willey (1979) quoted the observations at ICRISAT that pigeonpeas nodulated better where the roots intermingled with those of intercropped sorghum, indicating the genuine intercropping advantage.

Data from 94 experiments on sorghum / pigeonpea intercropping were examined for evidence that stability of yield was greater with intercropping than in sole cropping. It was found that sole pigeonpea would fail 1 year in 5, sole sorghum 1 year in 8, but intercropping only 1 year in 36 (Rao and Willey, 1980).

2.7.4 Sweet potato

In field trials, sweet potato was one of the intercrops which were sown or planted in between two paired rows of maize (paired rows 45 cm apart and 147 cm between the paired rows). Under intercropping, sweet potato had no effect on grain yields of maize, and tuber yields (29 t / ha) were reduced by 10 % only (Cordero, 1978). Akhanda (1979) also reported that maize grain yields were not affected by sweet potato, grown as intercrop, and increased with the increase in plant population; the tuber yields of sweet potato were, however, reduced under intercropping. Maize grain yields were also not reduced due to intercropping with sweet potato, grown on pasture (Ahlawat and Samlal, 1979).

Chatterjee and Mandal (1975) reported that in sweet potato, hybrids 12, 5 and Cross-4 gave yields, ranging from 20 to 30 t / ha in about 200 days when planted any time between August and October,

in relatively fertile soils. The leaf area duration and the day degrees during the period of tuber formation had significant relationship with tuber yields (r = 0.81 and 0.51, respectively). Tuber bulking was favoured at 4 to 6 leaf area indices and at mean temperatures ranging from 23 to 27°C during mid-October to mid-November and mid-February to mid-March. May-planted crop gave good vegetative growth but low tuber yields,while January-planted crop had poor vegetative growth and low tuber yields. In Tripura, sweet potato varieties were planted in April to October during 1977 - 79, and highest tuber yield (26.2 - 28.7 t / ha from cv. Cross-4) was obtained from July-planting (Rai, et al, 1982). Kamalam et al. (1978) reported that higher tuber yield of sweet potato by planting in July - October was due to favourable rainfall and temperature prevailing at the time.

From a date of planting trial with sweet potatoes in Solomon Islands, highest tuber yields (9.0 - 15.7 t / ha) were obtained during September to February, when harvesting was made at 120 days after planting (Gollifer, 1980). Bowers et al. (1978) reported that the yield of grade 1 and marketable tubers of sweet potato, harvested on 5 dates at 90 - 150 days after transplanting, increased with increasing delay in harvesting. Ahmed and Samad (1976) reported that planting in November gave the highest yield of sweet potato and the yield declined with delay in planting. This is also supported by Toib and Rashid (1976). Shanmugavelu et al. (1972), however, obtained highest tuber yield when planted in early October.

Mean daily solar radiation during 3, 2 and 1 month periods preceeding harvest was positively correlated with tuber yields.

Vine yield was negatively correlated for 1 month period preceeding harvest. Tuber yields and rainfall were negatively correlated (Gollifer, 1980). Haynes (1970) considered that as tuberization was dependent on adequate soil aeration, the high soil moisture and consequent low soil oxygen content, characteristic of the wet season, might be important in restricting tuberization. Watanabe (1979) reported that soil hardiness did not affect dry matter distribution until it reached 5 kg / cm^2, and it was shown that the distribution was affected by soil aeration rather than hardness. Formation of the tubers was delayed when soil O_2 level was low, soil N content was high or soil K content was low. Among 4 spacings of 30, 40, 50 and 60 cm in row, Bouwkamp and Scott (1980) obtained highest tuber yield of sweet potato at the closest spacing, the yields decreased linearly with wider spacing.

2.8 Summary and scope of work

Earlier works (Aiyer, 1949; Raheja, 1953, 1971, 1973) showed advantages of intercroppings in crop yields, particularly under limitations of resources like water and fertilizer. Intercroppings also showed advantages when such cropping systems were exposed to the hazards of pest and disease incidences or other weather hazards like drought and heavy rains etc. Later investigations (as reviewed by Willey, 1979) further gave evidences that under intercroppings, the physical resources like water, radiation, fertility of the soil at different depths and applied fertilizers were more productively utilised under intercropping system than under sole cropping; the advantages accrued were more under limited resources than under adequacy of resources.

Fairly a good amount of growth analytical work on the intercropping of maize with legumes or of pigeonpea with short-growing legumes and cereals, have been done during the last 10 years and have enunciated useful principles for studies on competitive relationship between the two component crops. Most of the works have showed greater advantages in intercropping where competitions are 'temporal' as compared to 'spatial'.

Sweet potato, whose vines trail on the ground, is a very high colorie producing food crop (mostly starch). It provides live mulch over the soil surface for a long period and has the potentiality for tuberization when the temperature is a bit warmer than that usually required by potato. This crop is usually a long duration crop (180 - 200 days). This may provide scope to grow another short duration cereal or legume crop, as an intercrop with sweet potato. From the available literature it appears that not much work has been done on the intercropping system with sweet potato and there is good scope to work on this aspect of intercropping.

3. MATERIALS AND METHODS

3.1 Experimental site

A number of field experiments were conducted in humid sub-tropics of West Bengal to analyse the growth and yield potentiality of the intercropping systems, when sweet potato was grown in association with soybean under different spatial arrangements and also with other crops. The investigations were carried out during the years from 1977 - 78 to 1980 - 81, at the Central Research Farm of Bidhan Chandra Krishi Viswavidyalaya. The farm is situated at approximately 23.5°N latitude, 89°E longitude and at 9.75 m above sea level.

3.2 Experimental soil

The experimental soil is alluvial and of sandy loam texture with good drainage facilities. The physico-chemical properties of the soil have been summarised in Table 3.1.

Table 3.1 Physico-chemical properties of the experimental soil

Clay %	Silt %	Fine sand %	Coarse sand %	Total N %	Available P (kg/ha)	Available K (kg/ha)	CEC me/ 100 g	pH
21.5	35.0	37.0	6.5	0.064	15.4	52.0	10.4	6.8

3.3 Climate

The experimental area falls under the sub-tropical humid climate. The average annual rainfall of the area is 1512 mm and

the mean temperature ranges from 10° to 37°C. Broadly, there are three distinct seasons, viz. (i) dry and hot season (March to May), (ii) wet season (June to October) and (iii) cold season (November to February).

3.3.1 Temperature

The atmospheric temperature begins to rise from the last week of January and reaches its maximum up to 37°C in the months of April-May. It remains high till the last week of September. The minimum temperature is usually low in the last week of December. The winter is mild and short (Table 3.2; Fig. 3.1).

3.3.2 Rainfall

The normal date of arrival of the monsoon (south-west) is seventh June in Calcutta (48 km south of the experimental area). It usually withdraws by the middle of October. About 77 % of the total rainfall occurs during June to September, 9 % during October-November, 2 % during December to February and 12 % during March to May (Table 3.2; Fig. 3.1).

3.3.3 Relative humidity

The average relative humidity of the area ranges from 52 to 85 % throughout the year (Table 3.2; Fig. 3.1). Maximum humidity is observed during the months of August-September and minimum during the winter months.

3.3.4 Radiation receipt

The mean radiation receipts throughout the year ranges from

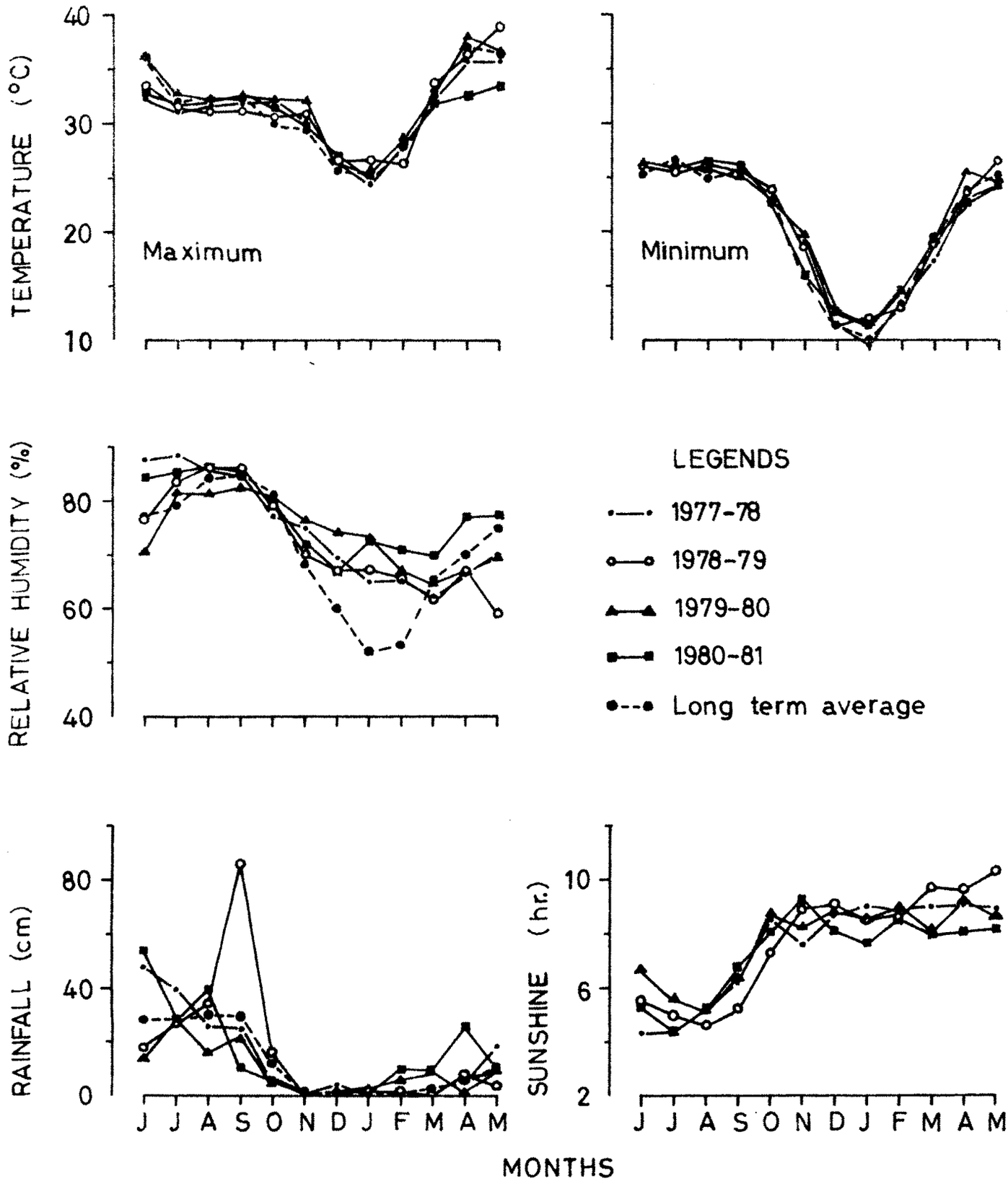

Fig. 3.1 DISTRIBUTION OF TEMPERATURE, RELATIVE HUMIDITY, RAINFALL AND SUNSHINE PERIOD

570 cal / cm^2 / day in the month of May to 333 cal / cm^2 / day in December. This is usually related with the period of sunshine hours (Table 3.2; Fig. 3.1).

3.3.5 Photoperiod

The day length varies from 11 hours 31 minutes in the month of December to 14 hours 27 minutes in the month of June. The lengths of day and night are equal on 23rd March and 23rd September.

3.4 Experimental details

3.4.1 Experiment number 1

3.4.1.1 Experiment number 1a

Title : Intercropping of soybean with sweet potato (1977 - 78)

Objective : To study the growth and yield performances of soybean (Glycine max L. Merr.) and sweet potato (Ipomoea batatas L. Lam.) when grown as sole and as intercrop under four spatial arrangements and three timings of planting of sweet potato.

Design : The experiment was laid out in Randomised Block Design, as a complex experiment with different factors augmented by introducing extra plots of sole crop.

Replication : Four

Treatment :

A. Sole cropping of soybean

(i) Soybean (45 cm apart rows)

Table 3.2 Meteorological data pertaining to the years of experimentation

Month	Max. temperature (°C)					Min. temperature (°C)					Mean relative humidity (%)					Period of bright sunshine (hrs.)				Rainfall (mm)					Solar radiation receipt (cal/cm²/day)
	1977 - 78	1978 - 79	1979 - 80	1980 - 81	LTA*	1977 - 78	1978 - 79	1979 - 80	1980 - 81	LTA*	1977 - 78	1978 - 79	1979 - 80	1980 - 81	LTA*	1977 - 78	1978 - 79	1979 - 80	1980 - 81	1977 - 78	1978 - 79	1979 - 80	1980 - 81	LTA*	LTA**
Jun	32.5	33.4	36.3	32.6	36.3	25.4	26.1	26.5	25.9	25.2	87.5	76.5	70.5	84.5	77.0	4.3	5.5	6.7	5.3	477.6	175.8	139.5	544.0	281.5	397
Jul	31.2	31.6	32.8	31.7	32.1	26.2	25.6	26.0	26.3	26.7	88.5	83.5	81.5	85.5	79.3	4.4	5.0	5.6	4.2	393.7	268.0	285.6	290.2	290.9	410
Aug	31.6	31.3	32.3	32.0	32.4	25.8	26.0	25.9	26.4	24.8	85.5	86.0	81.5	86.0	84.2	5.3	4.6	5.2	5.3	256.9	346.5	160.9	394.2	296.4	363
Sep	31.8	31.1	32.7	32.4	32.4	25.6	25.5	25.1	26.2	25.5	84.5	86.0	82.5	85.0	84.6	6.2	5.2	6.4	6.8	247.9	852.4	214.4	108.7	294.6	367
Oct	32.0	30.7	32.3	31.6	30.0	22.9	23.8	22.9	22.6	23.7	77.0	79.0	80.5	80.0	80.8	8.5	7.3	8.8	8.1	40.3	159.7	51.4	61.7	116.6	390
Nov	30.3	30.9	32.2	29.8	29.5	19.1	18.4	19.7	15.9	16.2	75.0	70.0	76.5	72.0	68.3	7.6	8.9	8.3	9.3	5.4	0.4	0.5	0.0	14.8	358
Dec	26.3	26.4	26.3	26.9	25.7	11.3	11.4	12.5	12.3	11.2	69.5	67.0	74.0	67.0	59.8	8.7	9.1	8.9	8.1	43.4	0.3	20.0	0.0	3.6	333
Jan	24.4	26.6	25.8	25.1	25.4	9.5	12.1	11.6	11.3	10.0	65.0	67.0	73.5	73.0	52.1	9.0	8.5	8.6	7.7	0.0	24.4	31.9	9.5	9.4	351
Feb	27.6	26.2	28.9	27.7	27.7	13.4	13.0	14.6	14.7	13.2	65.0	65.5	67.0	71.0	53.0	8.9	8.6	9.0	8.5	4.8	21.8	62.7	101.0	12.9	431
Mar	32.5	33.7	32.9	31.9	32.9	17.3	18.8	19.1	19.2	19.7	62.0	61.5	65.0	70.0	65.4	9.0	9.7	8.2	8.0	37.5	4.4	89.0	92.7	25.0	492
Apr	35.8	36.3	38.0	32.5	36.8	23.3	23.7	25.5	22.7	23.9	66.5	67.0	67.0	77.0	69.7	9.1	9.6	9.3	8.1	56.9	85.9	13.8	268.3	61.7	540
May	35.7	38.8	36.5	33.3	36.4	24.2	26.5	24.8	24.2	25.2	70.0	59.0	69.5	77.5	65.1	8.9	10.3	8.7	8.2	191.1	34.9	117.5	117.6	104.2	570
Total																				1755.5	1974.5	1187.2	1987.9	1511.6	

LTA* = Long term average (monthly mean of 25 years from 1956 to 1980, from Chinsura)
LTA** = Long term average (monthly mean of 11 years from 1969 to 1979, from Alipore)

B. Spatial arrangement of sweet potato (Fig. 3.2)

(i) Sweet potato only (spacing 60 cm x 30 cm)

(ii) Soybean / sweet potato : One row of soybean in between two rows of normally spaced (60 cm x 30 cm) sweet potato; briefly designated as 1 : 1 (rows 30 cm apart)

(iii) Soybean / sweet potato : One row of soybean in between 2 rows of sweet potato spaced at twice (120 cm) the normal distance with plant to plant distance 15 cm (i.e., half of the normal plant to plant spacing); briefly designated as 1 : 1 (rows 60 cm apart)

(iv) Soybean / sweet potato : Two rows of soybean in between 2 rows of sweet potato spaced at twice (120 cm) the normal distance with plant to plant distance 15 cm (i.e., half of the normal plant to plant spacing); briefly designated as 2 : 1 (rows 40 cm apart)

(v) Soybean / sweet potato : Paired rows of sweet potato with alternating paired rows of soybean (plant to plant distance of sweet potato 30 cm); briefly designated as 2 : 2 (rows 30 cm apart)

C. Timing of planting of sweet potato

D_1 = At the time of sowing of soybean (0 DAS)

D_2 = 45 days after sowing of soybean (45 DAS)

D_3 = 90 days after sowing of soybean(90 DAS)

Thus, there were sixteen [(5 x 3) + 1 = 16] treatment combinations.

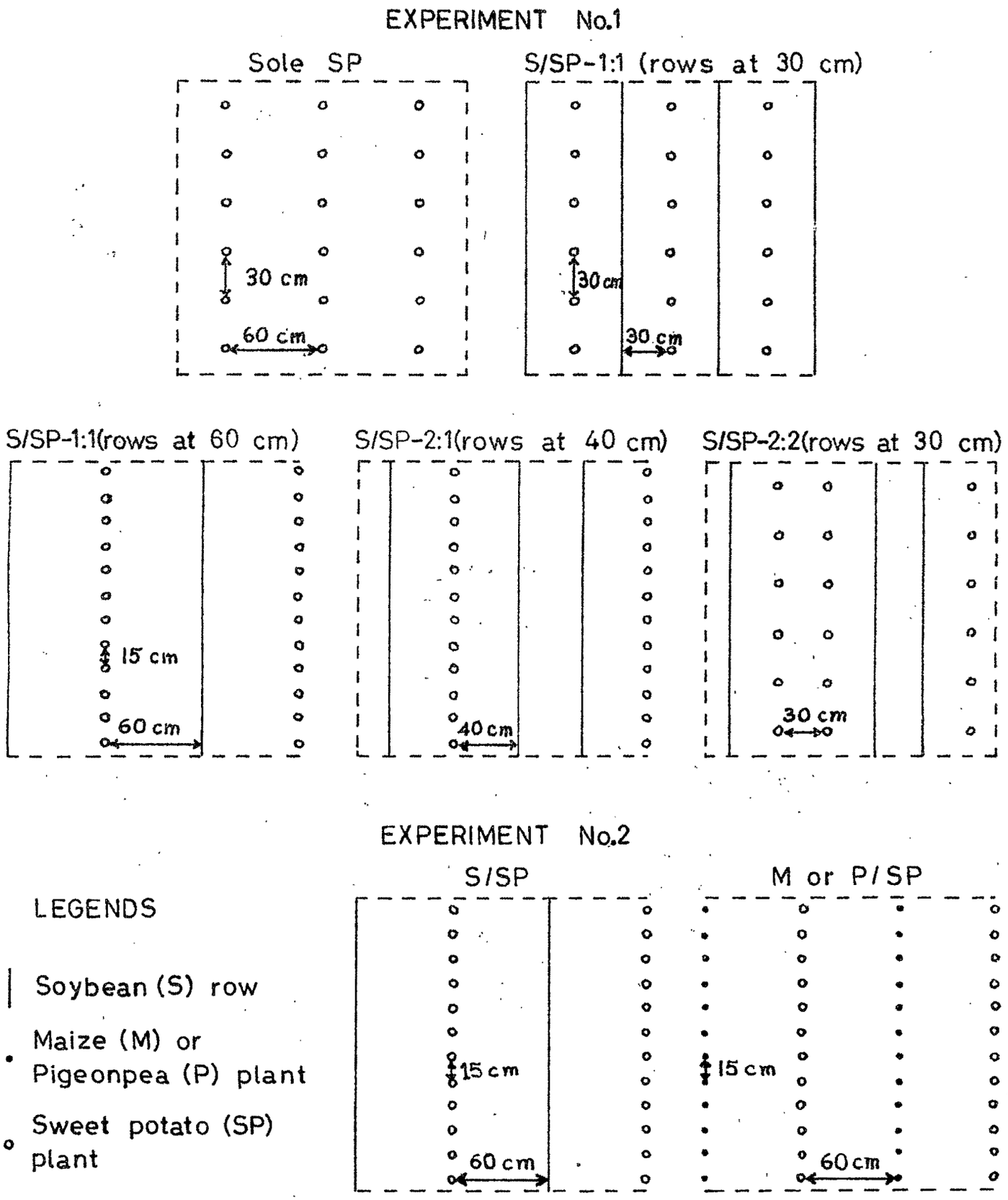

Fig. 3.2 SPATIAL ARRANGEMENTS FOR INTERCROPPING

Variety : A high yielding dwarf variety Bragg, maturing in 110 - 115 days, was used in case of soybean. A local variety of sweet potato was used in the experiment (1977 - 78).

Plot size : The gross plot size was 16.8 m^2 (7 m x 2.4 m) and the net plot size was 6.0 m^2 (5 m x 1.2 m).

Time of sowing : Soybean crop was sown by middle of July and sweet potato was planted as described earlier.

Fertilizer : The fertilizers were added at the rate of 25 kg N, 75 kg P_2O_5 and 75 kg K_2O / ha, in the form of urea, single super phosphate and muriate of potash, respectively, as basal dose. Nitrogen was top dressed at 50 kg N / ha in two equal splits to sweet potato rows only. The quantity of fertilizers per plot was divided equally into total number of rows of the plot and was applied in the respective rows of the crop / crops. In case of soybean, fertilizer was applied in furrows made in both sides of the crop row and mixed with the soil to avoid germination hazards.

Irrigation : Irrigation was applied in case no rainfall was received in three consecutive weeks.

Plant protection : Plant protection measures were taken as per need, and the crops were relatively kept free from insect pests and diseases.

Intercultural operations : The weeds were controlled manually and the plots were kept free from weed. Hoeing of the soil and earthing up along the crop rows were done twice in accordance with the proper soil moisture condition, before close up

of the space between the rows by crops. The vines were lifted time to time to discourage root formations at the nodes, other than the places where the plants were established.

3.4.1.2 Experiment number 1b

Title : Intercropping of soybean with sweet potato (1978 - 79)

The experiment as described in Experiment number 1a was repeated in the year 1978 - 79 with the following modifications:

1. Variety : The local variety of sweet potato was replaced with cv. H-268, a hybrid variety developed from Central Tuber Crop Research Institute, Trivandrum.

2. Plot size : The gross plot size of the experiment was 33.6 m^2 (7 m x 4.8 m) and the net plot size was 12.0 m^2 (5 m x 2.4 m).

3.4.1.3 Experiment number 1c

Title : Intercropping of soybean with sweet potato (1979 - 80)

The experiment number 1b was repeated in 1979 - 80 with the details, as stated earlier in Experiment number 1b.

3.4.2 Experiment number 2

3.4.2.1 Experiment number 2a

Title : Intercropping of soybean, maize and pigeonpea with sweet potato (1978 - 79)

Objective : To study the growth and yield performances of crops under sole and intercropping systems, when soybean, maize (*Zea mays* L.) and pigeonpea (*Cajanus cajan* L. Millsp.) were intercropped with sweet potato planted on different dates.

Design and replication : Same as in Experiment number 1

Treatment :

A. Sole cropping of grain crops

(i) Soybean (45 cm apart rows)

(ii) Maize (spacing 60 cm x 30 cm)

(iii) Pigeonpea (spacing 60 cm x 30 cm)

B. Cropping (with sweet potato)

(i) Sweet potato only (spacing 60 cm x 30 cm)

(ii) Soybean / sweet potato

(iii) Maize / sweet potato

(iv) Pigeonpea / sweet potato

C. Timing of planting of sweet potato

D_1 = At the time of sowing of grain crops (0 DAS)

D_2 = 45 days after sowing of grain crops (45 DAS)

D_3 = 90 days after sowing of grain crops (90 DAS)

Thus, there were fifteen [(4 x 3) + 3 = 15] treatment combinations.

Spatial arrangement for intercropping : One row of grain crop (soybean or maize or pigeonpea) in between 2 rows of sweet potato spaced at twice (120 cm) the normal distance, with plant to plant distance 15 cm (i.e., half of the normal plant to plant spacing). In the intercropping plots, plant to plant distance of maize and pigeonpea was 15 cm and thus plant populations of maize, pigeonpea and sweet potato were kept equal, in both sole and intercropping situations (Fig. 3.2).

Variety : The varieties Bragg, Diara Composite (maturing in 95 days) and AS-8 were used in cases of soybean, maize and pigeonpea, respectively. Local variety of sweet potato was used in the experiment.

Plot size : The gross and net plot sizes were 16.8 m^2 (7 m x 2.4 m) and 6.0 m^2 (5 m x 1.2 m), respectively.

Time of sowing : The experiment was sown by middle of July.

Fertilizer : A basal dose of fertilizers at 25 kg N, 75 kg P_2O_5 and 75 kg K_2O / ha were applied for all the crops. Top dressing of nitrogen at 50 kg N / ha was made in two equal splits to maize and sweet potato crops only.

The other details of the experiment were similar to those mentioned in Experiment number 1.

3.4.2.2 Experiment number 2b

Title : Intercropping of soybean, maize and pigeonpea with sweet potato (1979 - 80)

The experiment was repeated in 1979 - 80 as per details stated in Experiment number 2a with the following modifications:

1. Treatments :

A. Sole cropping of grain crops

(i) Soybean (45 cm apart rows)

(ii) Maize (spacing 60 cm x 30 cm)

(iii) Pigeonpea (spacing 60 cm x 30 cm)

B. Variety of sweet potato :

SP_1 = cv. H-268 and SP_2 = Local

C. Cropping (with sweet potato)

(i) Sweet potato only (spacing 60 cm x 30 cm)

(ii) Soybean / sweet potato

(iii) Maize / sweet potato

(iv) Pigeonpea / sweet potato

D. Timing of planting of sweet potato

D_1 = At the time of sowing of grain crops (0 DAS)

D_2 = 45 days after sowing of grain crops (45 DAS)

Thus, there were nineteen [(2 x 4 x 2) + 3 = 19] treatment combinations.

2. Plot size : The gross and net plot sizes were 25.2 m^2 (7 m x 3.6 m) and 12.0 m^2 (5 m x 2.4 m), respectively.

3.4.2.3 Experiment number 2c

Title : Intercropping of soybean, maize and pigeonpea with sweet potato (1980 - 81)

The experiment number 2b was repeated in the year 1980 - 81 with following modifications :

Variety of sweet potato

SP_1 = cv. H-268 and SP_2 = cv. Pusa Safed

Timing of planting of sweet potato

D_1 = At the time of sowing of grain crops (0 DAS)

D_2 = 90 days after sowing of grain crops (90 DAS)

3.5 Soil / crop management

The land was prepared with the help of wooden plough and plank. The experiment was laid out with due consideration to adequate drainage and irrigation facilities. Aldrin 5 % was applied at the rate of 30 kg / ha before final land preparation to combat the attack of soil insects. Seeds were treated with Bavistin at the rate of 2.5 g / kg of seed before sowing. Soybean seed was inoculated with Rhizobium culture after moistening the seed. Sweet potato vines with leaves were cut into pieces of about 30 cm long. Those pieces were planted by inserting into the soil at an angle and about one-half of their length beneath the soil. Maize and pigeonpea seeds were sown by dibbling to maintain the proper spacing. Soybean was also sown manually in solid rows. For planting of sweet potato on second and third dates of planting, plots were prepared with the help of spades. The insecticides Nuvan, Dimecron, Sumithion

and Thimet 10 G were applied as and when required. During long drought (3 weeks without rainfall) the crop / crops were irrigated. The weeds were controlled manually and the plots were kept free from weeds. The crops were harvested as and when they appeared to be matured, i.e., 95, 110 - 115 and 220 - 240 days after sowing of maize, soybean and pigeonpea, respectively. Sweet potato was harvested at 200, 180 and 150 days after planting in the middle of July, second fortnight of August and middle of October, respectively. Details of operations have been summarised in Calendar of operations (Appendix I).

3.6 Method of recording biometrical observations

3.6.1 Dry matter accumulation

To determine the dry matter accumulation by the different parts of the plants, at successive growth stages, destructive plant samplings were made from each plot at different stages. Sampling was done from the part of the plot, kept reserved for destructive sampling. In case of sampling of the grain crops (soybean, maize and pigeonpea), plants were cut at the ground level from one metre row length selected at random; but for sampling of sweet potato, a quadrat of 1.0 metre square was placed on the row at random and the shoots inside the quadrat were collected. Tubers were then collected with the help of spade from the same area. The fresh weights of shoot and tuber were recorded separately. The shoots were separated into leaf, stem, pod or cob. All the samples were then dried in a hot air oven at a temperature of 90° to 100°C till the constant weight was obtained. At later stages, representative samples (500 g) of

fresh material were dried and weighed. The weights of different parts of the grain crops, collected from one metre row, were converted into weight / square-metre, taking into consideration, the average row spacing.

3.6.2 Light interception

With a view to determining the percent light intercepted by the canopy of taller plant and shorter plant, illumination meter readings were recorded. Recordings were made at three strata of the canopy, viz. (i) top of the taller plant, (ii) top of the shorter plant, and (iii) ground level at the same spot, in case of intercropping situation. Observations were recorded at the top of the canopy and at the ground level only in plots having sweet potato crop only. In every plot these readings were taken at three places selected randomly. The readings were taken along the sweet potato rows and were generally recorded at 10 a.m. Observations were taken by a Metralux - K light meter in lux which gave only the comparative light intensities rather than the actual solar radiation receipts. Light interception percentage was calculated with the following formulae :

$$I_1 = (A - C) \times 100 / A \text{ and } I_2 = (A - B) \times 100 / A$$

where, I_1 and I_2 are the percentages of light interception at ground level and at the top of shorter plant, respectively; and A, B and C are the light intensity readings, taken at the top of the tall and short crop plants and at the ground levels, respectively.

3.6.3 Yield

Net plot was demarcated at first, leaving the border of respective crop in every plot. Net plots were then harvested, threshed and weighed. In case of sweet potato, the tubers were collected, washed and weighed after cutting of the shoot at ground level.

3.7 Method of determining competition functions

3.7.1 Aggressivity

Aggressivity, as proposed by Mc Gilchrist (1965), gives a simple measure of how much the relative yield increase in species 'a' is greater than that for species 'b'. It is usually denoted by 'A' and can be written as follows :

$$A_{ab} = \frac{\text{Mixture yield of 'a'}}{\text{Expected yield of 'a'}} - \frac{\text{Mixture yield of 'b'}}{\text{Expected yield of 'b'}}$$

$$\text{i.e.,} \quad A_{ab} = \frac{Y_{ab}}{Y_{aa} \times Z_{ab}} - \frac{Y_{ba}}{Y_{bb} \times Z_{ba}}$$

where, A_{ab} = Aggressivity of species 'a' (in combination with 'b')

Y_{aa} = Pure stand yield of species 'a'

Y_{bb} = Pure stand yield of species 'b'

Y_{ab} = Mixture yield of species 'a' (in combination with 'b')

Y_{ba} = Mixture yield of species 'b' (in combination with 'a')

Z_{ab} = Sown proportion of species 'a' (in mixture with 'b')

Z_{ba} = Sown proportion of species 'b' (in mixture with 'a')

An Aggressivity value of zero indicates both the component species to be equally competitive. A species having positive value is dominant, and the other species in the mixture with negative value is dominated, the numerical values of both species being the same. Although the Aggressivity was proposed originally for replacement situations, yet it was generalized in the yield-per-unit-area form in other situations. Aggressivity values were calculated with a view to determining the competitive abilities of the experimental crops under different intercropping situations.

3.7.2 Land Equivalent Ratio

To evaluate the yield advantages under different intercropping situations Land Equivalent Ratio (LER) values were calculated. It has been defined as the relative land area under sole crops which is required to produce the yields achieved under intercropping. The LER values for the combined intercrop yields and also for the intercrop yield of each crop were calculated. The LER values were calculated with the following formulae :

$$L_a = \frac{Y_{ab}}{Y_{aa}} ; \qquad L_b = \frac{Y_{ba}}{Y_{bb}} ; \qquad LER = L_a + L_b$$

where, L_a, L_b and LER have denoted LER values for the intercrop yields of crop 'a', crop 'b' and the combined intercrop yields, respectively.

3.7.3 Competitive Ratio

Competitive Ratio (CR), as proposed by Willey and Rao (1980), is the ratio of the individual LERs of the two component crops,

correcting for the proportions in which the crops were initially sown. The CR values were calculated to quantify the competition between intercrops under different intercropping situations. The CR values were calculated with the following formula :

$$CR_a = (L_a / L_b) \times (Z_{ba} / Z_{ab})$$

where, CR_a is the Competitive Ratio of species 'a' in mixture with 'b'.

3.7.4 Monetary advantage

Monetary advantage, as suggested by Willey (1979), gives the absolute value of the genuine yield advantage in intercropping. It has been proposed to calculate monetary advantage on the basis of total LER value. In order to give proper weightage to both the component crops, monetary advantages have been calculated, in the present investigation, for each component crop separately as follows :

Monetary advantage of crop 'a' = Value of intercrop yield of 'a' x (L_a - proportion area under crop 'a') / L_a

Monetary advantage of crop 'b' = Value of intercrop yield of 'b' x (L_b - proportion area under crop 'b') / L_b

The monetary advantages of both the crops have been added together to obtain total monetary advantage. The value of produce was estimated on the basis of local price, at the rate of Rs.400/-,

Rs.250/-, Rs.400/- and Rs.75/- per quintal of soybean, maize and pigeonpea grains and sweet potato tubers, respectively.

3.7.5 Calorie return

The calorific values of economic yields of different experimental crops were calculated to evaluate the intercropping advantages on the basis of calorie return. The calorie returns from soybean, maize and pigeonpea crops were estimated on the basis of 335, 360 and 343 cal / 100 g of edible portion, respectively, as described in the 'FAO Food Composition Tables for International Use', quoted by Aykroyd and Doughty (1973). The value of sweet potato was estimated at 132 cal / 100 g of tuber (Weight and height chart and Indian food values - Hoechst).

3.8 Statistical analysis

The data were analysed statistically by the analysis of variance method described by Cochran and Cox (1967) and Panse and Sukhatme (1967). Error Mean Square by Fisher and Snedecor's F-test method was followed to test the significance of different sources of variations. The above books were also followed to work out the correlation co-efficient and regression analysis.

The standard error of means (S. Em ±) and the critical difference (C. D. at 5 %) values have been provided in the tables of results to compare the differences between the mean values.

4. RESULTS

4.1 Growth, yield and competition function : Experiment number 1

The experiment on 'Intercropping of soybean with sweet potato' was undertaken with the objective to study the growth and yield performance of soybean and sweet potato when grown as sole and as intercrop. This experiment was carried out for three years (1977 - 78 to 1979 - 80) as per details mentioned in the chapter on 'Materials and Methods'.

4.1.1 Dry matter accumulation

The dry matter accumulations in soybean and sweet potato were studied at different stages through destructive samplings during 1979 - 80 (Experiment number 1c).

4.1.1.1 Soybean

The total dry matter accumulation in soybean shoot was reduced due to intercropping (Table 4.1) at 57 days after sowing (DAS). The reduction was high under 1 : 1 arrangement (rows 60 cm apart) and more prominent when both the crops were planted simultaneously (57 %) as compared to that under sole cropping (273 g / m^2). Similar reduction in dry weight was observed at 107 DAS. At first sampling, the minimum reduction in total dry matter was recorded under 1 : 1 arrangement (rows 30 cm apart) when sweet potato was planted at 90 days after sowing of soybean (18 %). Total dry matter accumulation in soybean under this arrangement was not significantly higher than those of other arrangements; except in 1 : 1 (rows 60 cm apart) arrangements under three dates

Table 4.1 Dry matter accumulation in soybean shoot and sweet potato leaf (g / m^2) : Experiment number 1c (1979 - 80)

Treatment	Soybean shoot		Sweet potato leaf				
	57 DAS	107 DAS	57 DAS	107 DAS	159 DAS	194 DAS	249 DAS
Sole S	272.6	965.2					
SP planted at 0 DAS							
Sole SP			64.4	95.8	152.8	185.0	164.6
S / SP 1 : 1 (rows at 30 cm)	158.8	663.5	31.6	38.2	107.4	125.4	126.2
S / SP 1 : 1 (rows at 60 cm)	117.8	447.9	66.8	77.4	132.0	204.6	167.8
S / SP 2 : 1 (rows at 40 cm)	209.5	782.0	46.6	55.2	130.0	159.2	141.6
S / SP 2 : 2 (rows at 30 cm)	190.3	656.5	56.2	62.6	117.8	187.0	145.4
SP planted at 45 DAS							
Sole SP				64.8	114.6	182.3	173.6
S / SP 1 : 1 (rows at 30 cm)	193.5	996.4		5.4	53.8	87.8	89.0
S / SP 1 : 1 (rows at 60 cm)	139.1	575.0		34.8	112.4	168.6	179.4
S / SP 2 : 1 (rows at 40 cm)	204.3	1047.8		21.4	88.0	122.2	138.4
S / SP 2 : 2 (rows at 30 cm)	193.3	991.8		33.0	84.2	106.2	133.8
SP planted at 90 DAS							
Sole SP					67.2	98.0	151.0
S / SP 1 : 1 (rows at 30 cm)	223.3	862.2			51.6	81.0	109.6
S / SP 1 : 1 (rows at 60 cm)	146.2	527.7			65.0	89.0	151.6
S / SP 2 : 1 (rows at 40 cm)	199.5	855.3			44.0	80.0	126.2
S / SP 2 : 2 (rows at 30 cm)	199.4	896.3			43.8	69.2	109.6
S. Em ±	11.49	14.79	3.59	3.38	7.49	11.40	10.75
C. D. at 5%	33.18	42.70	11.06	9.81	21.63	32.95	31.09
S.A. x T.P.	NS	**		NS	NS	**	NS

Table 4.1 (continued)

Treatment	Soybean shoot		Sweet potato leaf				
	57 DAS	107 DAS	57 DAS	107 DAS	159 DAS	194 DAS	249 DAS
Spatial arrangement of sweet potato (S.A.)							
Sole SP				80.3	111.5	155.1	163.1
S / SP 1 : 1 (rows at 30 cm)	191.9	840.7		21.8	70.9	98.1	108.3
S / SP 1 : 1 (rows at 60 cm)	134.4	516.9		56.1	103.1	154.1	166.3
S / SP 2 : 1 (rows at 40 cm)	204.4	895.0		38.3	87.3	120.4	135.4
S / SP 2 : 2 (rows at 30 cm)	194.3	848.2		47.8	81.9	120.8	129.6
S. Em ±	6.64	8.54		2.39	4.32	6.50	6.21
C. D.at 5%	19.17	24.66		6.93	12.47	18.79	17.89
Timing of planting of sweet potato (T.P.)							
0 DAS	169.1	637.5		65.8	128.0	172.2	149.1
45 DAS	182.6	902.8		31.9	90.6	133.4	142.8
90 DAS	192.1	785.4			54.3	83.4	129.6
S. Em ±	5.75	7.39		1.51	3.35	5.09	4.81
C. D.at 5%	16.60	21.34		4.38	9.67	14.71	13.91

S = Soybean, SP = Sweet potato, DAS = Days after sowing of soybean,
NS = Not significant, ** = Significant at 1 %

of planting of sweet potato and in 1 : 1 (rows 30 cm apart) arrangement with sweet potato planted on first date. At 107 DAS, total dry matter accumulation in soybean was not reduced under the intercropping arrangements where sweet potato was planted at 45 days after sowing of soybean, except in the 1 : 1 (rows 60 cm apart) arrangement. Similar was the trend of differences when sweet potato was planted at 90 days after sowing of soybean. When sweet potato was planted simultaneously with soybean, the reduction in dry matter accumulation under intercropping was high and the reduction, was maximum, as in other earlier described cases, when soybean and sweet potato were established in 1 : 1 (rows 60 cm apart) arrangement.

Among the different spatial arrangements of intercropping, 1 : 1 arrangement of 60 cm apart rows produced minimum dry matter at both the dates of sampling (Table 4.1). This might also be due to reduction in number of rows of soybean per unit area. Other arrangements of rows produced comparatively higher dry matter of soybean per unit area on each sampling date as compared to 1 : 1 arrangement of rows 60 cm apart. Soybean under 2S : 1SP arrangement (rows 40 cm apart) accumulated maximum dry matter, which was more pronounced at second date of sampling.

Dry weight of soybean increased by 8 and 42 % at first and second dates of sampling, respectively, when sweet potato was planted at 45 days after sowing of soybean, as compared to the treatment where both crops were planted simultaneously. With further delay in planting of sweet potato in soybean crop the dry matter accumulation in soybean increased, except on the second

sampling date (107 DAS), when there was reduction in the dry matter accumulation in soybean. This might, probably, be due to the soybean root injury while planting of sweet potato vines at 90 DAS.

Under 2S : 1SP (rows 40 cm apart) arrangement, soybean accumulated significantly higher dry matter than in 1 : 1 (rows 30 cm apart) and 2 : 2 (30 cm apart rows) arrangements under first and second dates of planting of sweet potato; whereas at third date of planting of sweet potato these three arrangements showed no significant differences amongst themselves; the interaction between row arrangements and timings of planting of sweet potato was significant (Table 4.1).

4.1.1.2 Sweet potato

Sampling of sweet potato plants was done at 57, 107, 159, 194 and 249 days after first planting (DAS).

Leaf : Dry matter accumulation in sweet potato leaf increased up to 194 days and declined afterwards under the first date of planting (Table 4.1). Under second and third dates of planting of sweet potato, leaf dry weight continued to increase. When sweet potato was planted along with soybean, maximum reduction in leaf dry matter was recorded under 1 : 1 arrangement (rows 30 cm apart), throughout the growing season. Magnitude of reduction was high (51 to 60 %) up to 107 DAS. It declined thereafter (23 to 32 %) as compared to the leaf dry matter in sole cropping. The soybean crop was harvested at 115 days after sowing. Under simultaneous planting, 1 : 1 arrangement (rows 60 cm apart)

produced lower (19 %) leaf dry matter than that of sole crop at 107 DAS due to adverse competition from soybean. At subsequent stages, this arrangement continued to produce leaf dry matter equal to those of the sole crop. Similar effect was observed when sweet potato was planted at 45 days after soybean was sown. The differences among the spatial arrangements were reduced under third date of planting of sweet potato.

Significant effects of different spatial arrangements were found on the dry matter accumulation in sweet potato leaf at different growth stages (Table 4.1). Leaf dry weight per unit area in respect of 1 : 1 arrangement (rows at 60 cm) was reduced (30 %) at 107 DAS as compared to that of sole crop. In subsequent dates of sampling, the above spatial arrangement was equally effective in accumulating dry matter in sweet potato leaf as compared to the sole cropping of sweet potato. The soybean / sweet potato intercropping with 1 : 1 arrangement (rows 30 cm apart) proved to be least effective as far as leaf dry matter production was concerned. Under this arrangement, dry matter accumulation in sweet potato leaf was 73 and 34 % lower, respectively, at 107 days and at the subsequent sampling dates than those of the sole crop. The other two arrangements were similar to each other and showed intermediate effect of the above two extremes, in this respect.

Delay in planting of sweet potato caused significant reduction in dry matter accumulation on earlier samplings. A delay of 45 days in planting of sweet potato reduced leaf dry weight by 52 to 4 % at different stages of growth, as compared to

those under simultaneous planting. This magnitude of reduction decreased gradually with the advance in crop growth. The reduction in leaf dry matter, due to planting of sweet potato at 90 days after first planting was 58, 52 and 13 %, respectively, at 159, 194 and 249 days, in comparison to their values under simultaneous planting.

The interaction effect of different spatial arrangements of sweet potato and their timings of planting on the leaf dry matter production was significant at 194 DAS (Table 4.1). In the sweet potato crop, planted at 90 days after sowing of soybean, the differences in dry matter accumulation in sweet potato leaves, when grown under different spatial arrangements of intercropping as compared to their sole cropping, were not significant. But sweet potatoes planted on first and second dates of planting showed significant differences in dry matter accumulations in leaf under the two 1 : 1 arrangements, as discussed earlier.

Stem : Dry matter accumulation in sweet potato stem, when planted along with soybean (Table 4.2), continued to increase up to 194 days and remained more or less constant afterwards. Among the different row arrangements, 1 : 1 arrangement (rows 30 cm apart) produced minimum dry matter in stem at all sampling dates, when both the crops were established simultaneously. The stem dry matter under this arrangement was reduced by 22 to 51 % than those of the sole crops at different dates of sampling. At 1 : 1 arrangement (rows 60 cm apart) the dry matter accumulations in sweet potato stems were more (7 to 18 %) than under sole cropping,

Table 4.2 Dry matter accumulation in sweet potato stem (g / m^2) : Experiment number 1c (1979 - 80)

Treatment	57 DAS	107 DAS	159 DAS	194 DAS	249 DAS
SP planted at 0 DAS					
Sole SP	65.8	177.4	266.6	368.4	359.0
S/SP 1 : 1 (rows at 30 cm)	51.6	87.8	141.8	256.4	187.4
S/SP 1 : 1 (rows at 60 cm)	70.4	208.6	302.2	416.8	419.4
S/SP 2 : 1 (rows at 40 cm)	71.6	98.4	152.0	247.9	230.6
S/SP 2 : 2 (rows at 30 cm)	68.2	138.8	185.2	280.2	285.2
SP planted at 45 DAS					
Sole SP		48.4	139.4	220.2	242.6
S/SP 1 : 1 (rows at 30 cm)		5.8	32.6	102.4	115.8
S/SP 1 : 1 (rows at 60 cm)		32.4	108.0	164.0	171.2
S/SP 2 : 1 (rows at 40 cm)		13.8	68.4	115.8	173.8
S/SP 2 : 2 (rows at 30 cm)		29.0	83.2	123.2	192.0
SP planted at 90 DAS					
Sole SP			59.2	93.8	98.6
S/SP 1 : 1 (rows at 30 cm)			40.4	53.6	78.8
S/SP 1 : 1 (rows at 60 cm)			43.4	54.8	97.4
S/SP 2 : 1 (rows at 40 cm)			42.4	48.2	89.4
S/SP 2 : 2 (rows at 30 cm)			30.0	54.4	82.2
S. Em ±	6.04	8.76	10.25	13.11	25.02
C. D.at 5 %	NS	25.44	29.65	37.85	72.24
S.A. x T.P.		**	**	**	**

Table 4.2 (continued)

Treatment	57 DAS	107 DAS	159 DAS	194 DAS	249 DAS
Spatial arrangement of sweet potato (S.A.)					
Sole SP		112.9	155.1	227.5	233.4
S/SP 1 : 1 (rows at 30 cm)		46.8	71.6	137.5	127.3
S/SP 1 : 1 (rows at 60 cm)		120.5	151.2	211.9	229.3
S/SP 2 : 1 (rows at 40 cm)		56.1	87.6	137.3	164.6
S/SP 2 : 2 (rows at 30 cm)		83.9	99.5	152.6	186.5
S. Em ±		6.19	5.90	7.57	14.45
C. D. at 5 %		17.98	17.12	21.86	41.72
Timing of planting of sweet potato (T.P.)					
0 DAS		142.2	209.6	313.9	296.3
45 DAS		25.8	86.3	145.1	179.1
90 DAS			43.1	61.0	89.3
S. Em ±		3.90	4.58	5.86	11.19
C. D. at 5 %		11.33	13.26	16.92	32.31

S = Soybean, SP = Sweet potato, DAS = Days after sowing of soybean,
NS = Not significant, ** = Significant at 1 %

at different dates of sampling except at first and last dates of sampling. Between the other two arrangements (2S : 1SP and 2 : 2 alternate paired rows), the 2 : 2 arrangement recorded higher stem growth at 107 and 159 DAS under first date of planting of sweet potato. In all other cases, the differences were not significant.

The mean values of dry matter accumulation in sweet potato stem under different row arrangements indicated that 1 : 1 arrangement (rows 60 cm apart) was comparable with the sole crop throughout the growing season (Table 4.2). Dry matter production in sweet potato stem, under 1 : 1 row arrangement (rows 30 cm apart) was 40 to 59 % lower than under sole cropping. The other two arrangements of intercropping did not show much difference in stem dry matter accumulation. Forty five days' delay in planting of sweet potato caused 82 (at 107 DAS) to 40 (at 249 DAS) per cent reduction of dry matter production in stem as compared to those accumulated under simultaneous planting. Similarly, a delay of 90 days caused 81 to 70 % reduction of stem dry matter.

The differences in dry matter accumulation under different spatial arrangements with sweet potato were, in general, more prominent with early planting of sweet potato. These differences gradually decreased with delayed planting of sweet potato. When sweet potato was planted at 90 days after sowing of soybean, there was no difference among the crops established differently. The interaction of different spatial arrangements with timings of planting of sweet potato was significant (Table 4.2).

Tuber : Initiation of tubers and their bulking (Table 4.3) started early under 1 : 1 arrangement (rows 60 cm apart) and 2 : 2 (alternate paired rows 30 cm apart) arrangements under simultaneous planting. Tuber initiation was delayed under 1 : 1 arrangement (rows 30 cm apart). Sweet potato, when grown in association with soybean and planted simultaneously under 1 : 1 arrangement (rows 60 cm apart), accumulated dry matter in tuber as much as under sole cropping. Tuber production under this arrangement was even higher (11 %) than that of sole crop (685 g / m^2) at 194 DAS. Bulking rate was minimum under 1 : 1 arrangement (rows 30 cm apart). Under simultaneous planting tuber growth increased up to 194 days and remained more or less constant afterwards. Bulking rate was high during the period from 159 to 194 DAS. During this period maximum rate of tuber production (16.2 g / m^2 / day) was recorded under 1 : 1 arrangement (rows 60 cm apart), followed by sole cropping (12.6 g / m^2 / day), 2 : 2 alternate paired row arrangement (12.1 g / m^2 / day), 2S : 1SP (11.6 g / m^2 / day) and 1 : 1 arrangement with rows 30 cm apart (9.7 g / m^2 / day).

The mean tuber growth of sweet potato was reduced due to competition with soybean as compared to that of sole crop (Table 4.3) at all the three dates of sampling. The magnitude of reduction in dry matter of tuber, under different intercropping systems, decreased gradually with the advancement of growing period. The range of reduction from sole cropping varied from 49 to 17, 71 to 39, 77 to 47 and 81 to 51 %, respectively under 1 : 1 (rows 60 cm apart), 2 : 2, 2S : 1SP and 1 : 1 (rows 30 cm apart) row arrangements at different dates of sampling.

Table 4.3 Dry matter accumulation in sweet potato tuber (g / m^2) : Experiment number 1c (1979 - 80)

Treatment	57 DAS	107 DAS	159 DAS	194 DAS	249 DAS
SP planted at 0 DAS					
Sole SP		15.8	242.8	684.8	697.0
S/SP 1 : 1 (rows at 30 cm)			76.8	414.6	418.0
S/SP 1 : 1 (rows at 60 cm)	4.0	31.4	189.6	758.2	761.8
S/SP 2 : 1 (rows at 40 cm)		8.0	89.6	494.2	501.0
S/SP 2 : 2 (rows at 30 cm)	4.8	20.0	114.8	539.8	541.0
SP planted at 45 DAS					
Sole SP			161.6	550.0	572.0
S/SP 1 : 1 (rows at 30 cm)			2.2	57.2	154.2
S/SP 1 : 1 (rows at 60 cm)			21.4	220.0	301.6
S/SP 2 : 1 (rows at 40 cm)			3.4	134.2	173.8
S/SP 2 : 2 (rows at 30 cm)			3.0	140.8	236.0
SP planted at 90 DAS					
Sole SP				62.4	193.8
S/SP 1 : 1 (rows at 30 cm)				16.8	149.8
S/SP 1 : 1 (rows at 60 cm)				43.0	152.8
S/SP 2 : 1 (rows at 40 cm)				8.4	104.4
S/SP 2 : 2 (rows at 30 cm)				19.8	123.2
S. Em ±			11.45	23.85	32.92
C. D. at 5 %			33.22	68.86	95.05
S.A. x T.P.			**	**	**

Table 4.3 (continued)

Treatment	57 DAS	107 DAS	159 DAS	194 DAS	249 DAS
Spatial arrangement of sweet potato (S.A.)					
Sole SP			202.2	432.4	487.6
S/SP 1 : 1 (rows at 30 cm)			39.5	162.9	240.7
S/SP 1 : 1 (rows at 60 cm)			105.5	340.4	405.4
S/SP 2 : 1 (rows at 40 cm)			46.5	212.3	259.7
S/SP 2 : 2 (rows at 30 cm)			58.9	233.5	300.1
S. Em ±			8.10	13.77	19.01
C. D. at 5 %			23.50	39.76	54.89
Timing of planting of sweet potato (T.P.)					
0 DAS			142.7	578.3	583.8
45 DAS			38.3	220.4	287.5
90 DAS				30.1	144.8
S. Em ±			5.12	10.67	14.72
C. D. at 5 %			14.86	30.81	42.50

S = Soybean, SP = Sweet potato, DAS = Days after sowing of soybean,
** = Significant at 1 %

A delay of 45 days in planting of sweet potato, reduced the dry matter accumulation in tubers by 73 (at 159 DAS) to 51 (at 249 DAS) per cent and a delay of 90 days reduced the tuber growth by 95 (at 194 DAS) and 75 (at 249 DAS) per cent as compared to the dry matter accumulated in simultaneously planted sweet potato crop with soybean.

When sweet potato was planted late, the differences in dry matter accumulations in tubers due to different spatial arrangements were low, as compared to the earlier plantings of sweet potato; the interactions of spatial arrangements with timings of planting of sweet potato was significant (Table 4.3).

Total : Total (shoot + tuber) dry matter accumulation in sweet potato planted along with soybean, increased up to 194 DAS and tended to decline thereafter (Table 4.4). The rate of total dry matter accumulation in sweet potato was 2.3, 3.2, 7.2 and 16.5 g / m^2 / day, respectively, during 0 to 57, 58 to 107, 108 to 159 and 160 to 194 DAS under sole cropping system. Total dry matter accumulation under 1 : 1 arrangement of rows 60 cm apart was, more or less, equal up to 159 days and then exceeded the values of sole crop, when established simultaneously with soybean. Total dry matter accumulation was 11 % higher at 1 : 1 row arrangement (rows 60 cm apart) than under sole crop at 194 and 249 DAS. Under simultaneous planting, minimum amount of dry matter accumulated in sweet potato, throughout the growing period under 1 : 1 arrangement (rows 30 cm apart). Under this arrangement, reduction in total dry matter accumulation in sweet potato due to competition with soybean, varied from 31 to 56 % as compared to under sole crop.

Table 4.4 Total dry matter accumulation in sweet potato (g / m^2) : Experiment number 1c (1979 - 80)

Treatment	57 DAS	107 DAS	159 DAS	194 DAS	249 DAS
SP planted at 0 DAS					
Sole SP	130.2	289.0	662.2	1238.2	1220.6
S/SP 1 : 1 (rows at 30 cm)	83.2	126.0	326.0	796.4	731.6
S/SP 1 : 1 (rows at 60 cm)	141.2	317.4	623.8	1379.6	1349.0
S/SP 2 : 1 (rows at 40 cm)	118.2	161.6	371.6	901.3	873.2
S/SP 2 : 2 (rows at 30 cm)	129.2	221.4	417.8	1007.0	971.6
SP planted at 45 DAS					
Sole SP		113.2	415.6	952.5	988.2
S/SP 1 : 1 (rows at 30 cm)		11.2	88.6	247.4	359.0
S/SP 1 : 1 (rows at 60 cm)		67.2	241.8	552.6	652.2
S/SP 2 : 1 (rows at 40 cm)		35.2	159.8	372.2	486.0
S/SP 2 : 2 (rows at 30 cm)		62.0	170.4	370.2	561.8
SP planted at 90 DAS					
Sole SP			126.4	254.2	443.4
S/SP 1 : 1 (rows at 30 cm)			92.0	151.4	338.2
S/SP 1 : 1 (rows at 60 cm)			108.4	186.8	401.8
S/SP 2 : 1 (rows at 40 cm)			86.4	136.6	320.0
S/SP 2 : 2 (rows at 30 cm)			73.8	143.4	315.0
S. Em ±	6.66	9.05	15.30	30.13	43.96
C. D. at 5 %	20.52	26.26	44.18	87.00	126.93
S.A. x T.P.		**	**	**	**

Table 4.4 (continued)

Treatment	57 DAS	107 DAS	159 DAS	194 DAS	249 DAS
Spatial arrangement of sweet potato (S.A.)					
Sole SP		201.1	401.4	815.0	884.1
S/SP 1 : 1 (rows at 30 cm)		68.6	168.9	398.4	476.3
S/SP 1 : 1 (rows at 60 cm)		192.3	324.7	706.3	801.0
S/SP 2 : 1 (rows at 40 cm)		98.4	205.9	470.0	559.7
S/SP 2 : 2 (rows at 30 cm)		141.7	220.7	506.9	616.1
S. Em ±		6.40	8.83	17.40	25.38
C. D. at 5 %		18.57	25.50	50.24	73.28
Timing of planting of sweet potato (T.P.)					
0 DAS		223.1	480.3	1064.5	1029.2
45 DAS		57.8	215.2	499.0	609.4
90 DAS			97.4	174.5	363.7
S. Em ±		4.05	6.84	13.48	19.66
C. D. at 5 %		11.75	19.75	38.92	56.77

S = Soybean, SP = Sweet potato, DAS = Days after sowing of soybean,
** = Significant at 1 %

During the period from 107 to 194 DAS, the soybean / sweet potato intercropping under 2 : 2 (alternate paired rows) arrangement showed superiority over 2S : 1SP arrangement regarding dry matter accumulation in sweet potato.

The mean dry matter accumulation was reduced (Table 4.4) due to intercropping with soybean, under 1 : 1 arrangement (rows 60 cm apart), except in the early stage. The minimum reduction (4 to 19 %) in total dry matter was recorded with the above arrangement of intercropping. As in the cases of leaf, stem and tuber, there was maximum reduction in total dry matter (46 to 66 %) under the 1 : 1 arrangement (rows 30 cm apart). The other two arrangements of intercropping (2 : 2 and 2S : 1SP) failed to show wide difference between them.

The trend of variation in total dry matter accumulation in sweet potato at different sampling dates due to different timings of planting (Table 4.4) was similar to what has been described earlier in respect of dry matter accumulation in stem.

4.1.2 Light interception

Percentage of light intercepted by the sweet potato crop on different dates was calculated as per methods described in 'Materials and Methods'.

4.1.2.1 Experiment number 1a (1977 - 78)

The percentage of light intercepted by sweet potato crop planted at the time of sowing of soybean increased up to about 143

DAS, and the values continued to increase up to 199 days, when sweet potato was relay planted (Table 4.5). Under the different systems of intercropping, interception of light by sweet potato foliage was reduced to the maximum at 86 DAS. Sweet potato crop, when planted simultaneously under 1 : 1 arrangement (rows 30 cm apart), intercepted 10 to 72 % less light than under the sole crops. Sweet potato, planted along with soybean under 1 : 1 arrangement (rows 60 cm apart), intercepted as much light as in the case of sole cropping, at the later stages of growth. In the early stage up to 86 days, light absorption was, however, lower than under sole crop due to intercropping. Percentage of light interception was maximum (93 %) at 143 days in 1 : 1 arrangement (rows 60 cm apart). The other two arrangements were equally effective in intercepting light throughout the growing period under simultaneous planting.

Sweet potato, when grown in association with soybean under 1 : 1 row arrangement (rows 60 cm apart), was as much efficient as sole cropping of sweet potato at 114 days and onwards. There was not much difference between the percentages of light intercepted by sweet potato established under 2S : 1SP and 2 : 2 alternate paired row arrangements. These two arrangements of rows intercepted lesser amount of light as compared to the crop established in 1 : 1 arrangement (rows 60 cm apart), except at the last date, when there was no significant difference between the treatments.

Sweet potato crop, planted at 45 days after sowing of soybean, intercepted solar radiation significantly lesser than that of

Table 4.5 Percent light interception by sweet potato : Experiment number 1a (1977 - 78)

Treatment	58 DAS	86 DAS	114 DAS	143 DAS	171 DAS	199 DAS
SP planted at 0 DAS						
Sole SP	70.0	78.3	84.1	88.7	87.0	81.0
S/SP 1:1(rows at 30 cm)	21.1	5.2	51.0	79.7	74.0	70.6
S/SP 1:1(rows at 60 cm)	58.6	49.5	81.9	92.6	89.8	84.2
S/SP 2:1(rows at 40 cm)	49.7	15.7	55.5	74.5	81.6	78.1
S/SP 2:2(rows at 30 cm)	42.2	14.4	58.1	85.0	84.7	84.0
SP planted at 45 DAS						
Sole SP		68.3	79.8	88.9	93.2	89.3
S/SP 1:1(rows at 30 cm)		1.9	25.6	50.4	64.3	69.6
S/SP 1:1(rows at 60 cm)		30.7	71.5	85.7	84.3	85.5
S/SP 2:1(rows at 40 cm)		9.5	55.4	65.0	80.0	80.3
S/SP 2:2(rows at 30 cm)		6.4	47.1	60.2	74.1	79.0
SP planted at 90 DAS						
Sole SP			45.2	57.1	82.0	86.2
S/SP 1:1(rows at 30 cm)			24.2	33.3	54.9	67.4
S/SP 1:1(rows at 60 cm)			40.0	52.1	71.1	73.4
S/SP 2:1(rows at 40 cm)			25.3	55.0	66.2	74.2
S/SP 2:2(rows at 30 cm)			30.2	60.1	67.7	75.0
S. Em ±	2.10	2.83	4.16	4.39	3.43	3.67
C. D. at 5%	6.47	8.21	12.01	12.68	9.90	10.60
S.A. x T.P.		NS	**	**	NS	NS

Table 4.5 (continued)

Treatment	58 DAS	86 DAS	114 DAS	143 DAS	171 DAS	199 DAS
Spatial arrangement of sweet potato (S.A.)						
Sole SP		73.3	69.7	78.2	87.4	85.5
S/SP 1:1(rows at 30 cm)		3.6	33.6	54.5	64.4	69.2
S/SP 1:1(rows at 60 cm)		40.1	64.5	76.8	81.7	81.0
S/SP 2:1(rows at 40 cm)		12.6	45.4	64.8	75.9	77.5
S/SP 2:2(rows at 30 cm)		10.4	45.1	68.4	75.5	79.3
S. Em ±		2.00	2.40	2.53	1.98	2.12
C. D. at 5 %		5.80	6.93	7.31	5.72	6.12
Timing of planting of sweet potato (T.P.)						
0 DAS		32.6	66.1	84.1	83.4	79.6
45 DAS		23.4	55.9	70.0	79.2	80.7
90 DAS			33.0	51.5	68.4	75.2
S. Em ±		1.26	1.86	1.96	1.53	1.64
C. D. at 5 %		3.66	5.37	5.66	4.42	4.73

S = Soybean, SP = Sweet potato, DAS = Days after sowing of soybean,
NS = Not significant, ** = Significant at 1 %

simultaneously planted sweet potato up to 143 days (Table 4.5), after which the differences were not wide. Sweet potato, planted at 90 days after sowing of soybean, absorbed light even less than that at second date of planting throughout the growing period.

The interaction effects of different spatial arrangements of sweet potato and their timings of planting on the light interception by sweet potato crop were significant at 114 and 143 DAS (Table 4.5). In both the dates, the decrease in interception of light due to delay of 45 days in planting was not appreciable under sole cropping and in 1 : 1 arrangement with wider row spacing (60 cm apart). This decrease was, however, high under 1 : 1 arrangement with narrow (30 cm) row spacing.

4.1.2.2 Experiment number 1b (1978 - 79)

Percentage light intercepted by sweet potato sole crop, planted at the time of sowing of soybean, increased gradually and became maximum (95 %) at 161 DAS and tended to decrease afterwards (Table 4.6). Light interception by simultaneously planted sweet potato, under 1 : 1 arrangement (rows 60 cm apart), was comparable with those of sole crop throughout the growing season, except at 93 days. At this stage the interception was lower by 17 % in comparison to that of sole crop, due to some obstructions created by the adjacent soybean foliage. The arrangements 2S : 1SP and 2 : 2 (alternate paired rows) caused comparatively lower interception of light by sweet potato as compared to 1 : 1 arrangement (60 cm apart rows). The other arrangement of intercropping, 1 : 1 (rows 30 cm apart) caused least percentages of light interception

Table 4.6 Percent light interception by sweet potato : Experiment number 1b (1978 - 79)

Treatment	71 DAS	93 DAS	143 DAS	161 DAS	170 DAS	188 DAS	202 DAS	230 DAS
SP planted at 0 DAS								
Sole SP	79.4	85.2	94.0	94.9	93.5	90.1	88.3	84.4
S/SP 1:1(rows at 30 cm)	18.4	10.9	69.5	80.5	83.1	82.0	81.2	76.9
S/SP 1:1(rows at 60 cm)	76.6	67.9	91.8	97.1	97.7	95.3	93.5	91.3
S/SP 2:1(rows at 40 cm)	54.2	41.9	80.8	91.1	90.2	89.4	85.2	84.4
S/SP 2:2(rows at 30 cm)	53.4	46.9	75.7	87.3	88.0	86.0	84.1	83.6
SP planted at 45 DAS								
Sole SP	50.0	68.4	87.8	90.1	90.6	90.3	94.4	94.0
S/SP 1:1(rows at 30 cm)	8.2	1.3	57.7	67.3	70.1	76.0	79.3	83.6
S/SP 1:1(rows at 60 cm)	35.3	30.0	79.0	91.9	94.6	96.0	97.2	96.8
S/SP 2:1(rows at 40 cm)	16.4	8.9	67.2	78.4	86.4	86.8	87.0	86.6
S/SP 2:2(rows at 30 cm)	12.8	7.4	65.7	75.7	84.9	90.5	91.0	87.2
SP planted at 90 DAS								
Sole SP			62.5	76.1	78.4	80.0	81.8	84.4
S/SP 1:1(rows at 30 cm)			48.0	65.0	75.0	78.2	79.2	81.2
S/SP 1:1(rows at 60 cm)			53.6	70.8	76.6	79.9	80.4	84.4
S/SP 2:1(rows at 40 cm)			41.3	68.5	72.7	76.5	77.2	85.0
S/SP 2:2(rows at 30 cm)			49.0	68.1	71.2	77.1	79.2	84.3
S. Em ±	2.75	3.52	4.45	4.07	4.69	4.76	4.11	4.01
C. D. at 5%	7.98	10.21	12.85	11.75	13.54	13.74	11.87	NS
S.A. x T.P.	**	**	NS	NS	NS	NS	NS	NS

Table 4.6 (continued)

Treatment	71 DAS	93 DAS	143 DAS	161 DAS	170 DAS	188 DAS	202 DAS	230 DAS
Spatial arrangement of sweet potato (S.A.)								
Sole SP	64.7	76.8	81.4	87.0	87.5	86.8	88.2	87.6
S/SP 1:1(rows at 30 cm)	13.3	6.1	58.4	70.9	76.1	78.7	79.9	80.6
S/SP 1:1(rows at 60 cm)	56.0	49.0	74.8	86.6	89.6	90.4	90.4	90.8
S/SP 2:1(rows at 40 cm)	35.3	25.4	63.1	79.3	83.1	84.2	83.1	85.3
S/SP 2:2(rows at 30 cm)	33.1	27.2	63.5	77.0	81.4	84.5	84.8	85.0
S. Em ±	1.95	2.49	2.57	2.35	2.71	2.75	2.37	2.31
C. D. at 5%	5.66	7.22	7.42	6.79	7.82	NS	NS	NS
Timing of planting of sweet potato (T.P.)								
0 DAS	56.4	50.6	82.4	90.2	90.5	88.6	86.5	84.1
45 DAS	24.5	23.2	71.5	80.7	85.3	87.9	89.8	89.6
90 DAS			50.9	69.7	74.8	78.3	79.6	83.9
S. Em ±	1.23	1.58	1.99	1.82	2.10	2.13	1.84	1.79
C. D. at 5%	3.57	4.58	5.75	5.26	6.06	6.15	5.31	NS

S = Soybean, SP = Sweet potato, DAS = Days after sowing of soybean,
NS = Not significant, ** = Significant at 1 %

by sweet potato, throughout the growing period. But the differences were reduced towards the end of growing season.

The effect of different row arrangements of sweet potato (Table 4.6) was similar to what has been observed in Experiment number 1a (1977 - 78). But the difference is that in the present experiment, 1 : 1 arrangement (rows 30 cm apart) was not significantly inferior to 2S : 1SP or 2 : 2 (alternate paired rows) arrangement at 143 days and onwards.

Interception of solar radiation was affected differently due to different timings of planting of sweet potato (Table 4.6). Light interception by sweet potato, planted at 45 days later than soybean, was fairly reduced up to 161 days, became equal during the period from 170 to 202 days and was higher afterwards, as compared to those at simultaneous planting. Percentage of light, intercepted by sweet potato planted at 90 days after sowing of soybean, decreased as compared to those of second and first dates of planting throughout the growing period, with the exception, that at 230 days there was no difference between first and third dates of planting, in this respect.

The interaction effect was significant at 71 and 93 DAS (Table 4.6). At 71 DAS, the arrangement 1 : 1 (rows 60 cm apart) was at par with sole cropping when sweet potato was planted along with soybean. But the above intercropping arrangement was inferior to sole cropping under second date of planting. On the other hand, 2 : 2 (alternate paired rows) arrangement was superior to 1 : 1 arrangement (rows 30 cm apart) under simultaneous planting, but they

were at par at second date of planting. At 93 DAS, 2S : 1SP and 2 : 2 alternate paired rows arrangements were superior to 1 : 1 (rows 30 cm apart) arrangement under simultaneous planting; but they were at par at second date of planting of sweet potato.

4.1.2.3 Experiment number 1c (1979 - 80)

The variation in light interception due to different cropping treatments (Table 4.7) was, more or less, similar to that of Experiment number 1b. Sole crop of sweet potato, planted at the time of sowing of soybean, intercepted 71 % light at 44 days which increased gradually to the extent of 93 % at 184 days and then declined. The 1 : 1 arrangement (rows 60 cm apart) was equally effective, except during the period from 67 to 79 days, when full sunlight was not available to the sweet potato crop. Light interception by sweet potato under this intercropping system reached to the extent of 95 % at 184 DAS. The effect of other arrangements, under first date of planting, was similar to observations as recorded in earlier years.

The effect of spatial arrangements on light interception (Table 4.7) was, more or less, similar to those described in earlier years. In respect of percentage of light intercepted by sweet potato, soybean / sweet potato intercropping under 1 : 1 arrangement (60 cm apart rows) was less effective up to 99 days, equally effective afterwards and then became more efficient at 248 DAS of soybean, as compared to the sole crop of sweet potato. The arrangement 1 : 1 (rows 30 cm apart) was observed to be the least effective one in this respect throughout the growing period,

Table 4.7 Percent light interception by sweet potato : Experiment number 1c (1979 - 80)

Treatment	44 DAS	67 DAS	79 DAS	99 DAS	128 DAS	139 DAS	184 DAS	248 DAS
SP planted at 0 DAS								
Sole SP	70.7	75.9	80.4	85.1	91.2	91.6	93.1	83.5
S/SP 1:1(rows at 30 cm)	29.4	4.6	3.0	20.8	81.2	82.7	84.7	81.8
S/SP 1:1(rows at 60 cm)	70.5	68.1	61.7	84.4	93.0	94.4	94.9	86.8
S/SP 2:1(rows at 40 cm)	32.8	15.9	15.0	39.9	82.4	86.7	87.7	84.3
S/SP 2:2(rows at 30 cm)	35.8	23.5	19.0	50.6	80.1	85.7	88.0	84.5
SP planted at 45 DAS								
Sole SP		45.0	64.8	83.2	87.0	88.2	92.5	83.2
S/SP 1:1(rows at 30 cm)		4.5	1.1	16.0	57.4	62.6	81.2	80.9
S/SP 1:1(rows at 60 cm)		39.3	33.0	71.3	81.0	84.3	96.0	92.3
S/SP 2:1(rows at 40 cm)		8.7	6.2	25.6	69.9	80.3	87.3	86.9
S/SP 2:2(rows at 30 cm)		15.4	8.4	41.3	79.0	82.2	91.7	91.8
SP planted at 90 DAS								
Sole SP					49.6	54.3	82.6	81.1
S/SP 1:1(rows at 30 cm)					53.4	64.7	80.5	78.4
S/SP 1:1(rows at 60 cm)					57.4	62.4	85.9	83.8
S/SP 2:1(rows at 40 cm)					43.2	62.6	82.2	81.8
S/SP 2:2(rows at 30 cm)					43.7	62.3	89.6	87.7
S. Em ±	2.98	2.57	2.80	3.16	3.42	3.41	3.82	3.49
C. D. at 5%	9.18	7.46	8.12	9.17	9.87	9.85	NS	NS
S.A. x T.P.		NS	NS	NS	**	**	NS	NS

Table 4.7 (continued)

Treatment	44 DAS	67 DAS	79 DAS	99 DAS	128 DAS	139 DAS	184 DAS	248 DAS
Spatial arrangement of sweet potato (S.A.)								
Sole SP		60.5	72.6	84.2	75.9	78.0	87.7	81.3
S/SP 1:1(rows at 30 cm)		4.6	2.1	18.4	64.0	70.0	82.1	80.4
S/SP 1:1(rows at 60 cm)		53.7	47.4	77.9	77.1	80.4	92.3	87.6
S/SP 2:1(rows at 40 cm)		12.3	10.6	32.8	65.2	76.5	85.7	84.3
S/SP 2:2(rows at 30 cm)		19.5	13.7	46.0	67.6	76.7	89.8	88.0
S. Em ±		1.81	1.98	2.23	1.97	1.97	2.21	2.02
C. D. at 5 %		5.25	5.75	6.47	5.69	5.69	NS	NS
Timing of planting of sweet potato (T.P.)								
0 DAS		37.6	35.8	56.2	85.6	88.2	88.7	83.4
45 DAS		22.6	22.7	47.5	74.9	79.5	89.7	87.0
90 DAS					49.5	61.3	84.2	82.6
S. Em ±		1.15	1.25	1.41	1.53	1.52	1.71	1.56
C. D. at 5 %		3.34	3.63	4.09	4.42	4.39	NS	NS

S = Soybean, SP = Sweet potato, DAS = Days after sowing of soybean,
NS = Not significant, ** = Significant at 1 %

although it was not always significantly inferior to 2S : 1SP arrangement. The other two arrangements of intercropping 2S : 1SP and 2 : 2 (alternate paired rows), showed, more or less, similar efficiency.

A delay of 45 days in planting reduced the light interception till 138 days, equalised at 184 days and increased the value at 248 days after soybean sowing, as compared to those of simultaneous planting (Table 4.7). Interception of solar radiation under third date of planting was always lower than those under second date of planting, but was equal to that of first planting at 248 days after sowing of soybean.

The interaction effect of different spatial arrangements of sweet potato and their different timings of planting on light interception by sweet potato was observed to be significant at 128 and 139 DAS (Table 4.7). At 128 DAS, sole cropping and 1 : 1 arrangement (rows 60 cm apart) were found to be superior to other arrangements under first date of planting; while under the third date of planting, sole cropping was not superior to other arrangements. At 139 DAS, 1 : 1 arrangement (rows 30 cm apart) was significantly inferior to sole cropping and 1 : 1 arrangement (rows 60 cm apart) under first and second dates of planting; but under third date of planting all arrangements were, more or less, equal.

4.1.3 Yield

4.1.3.1 Experiment number 1a (1977 - 78)

Soybean : Highest grain yield of soybean (2697 kg / ha) was obtained under sole cropping of soybean (Table 4.8). The yield

decreased significantly, when intercropped with sweet potato. The yield reduction was maximum (46 %) under 1 : 1 arrangement (rows 60 cm apart), planted simultaneously. The minimum yield reduction (15 %) was obtained under 2S : 1SP arrangement, when sweet potato was planted at 45 days after sowing of soybean. This intercropping treatment did not cause significant increase in soybean yield over those recorded in other intercropping treatments, except in the 1 : 1 arrangements (rows 60 cm apart).

Among the different spatial arrangements of intercropping, 1 : 1 row arrangement (rows 60 cm apart) produced significantly lower soybean yield, as compared to other arrangements; this might be also because of having soybean rows, half of the number maintained in other intercropping arrangements (Table 4.8). The other three row arrangements were at par in this respect. Planting of sweet potato on different dates did not show any significant effect on the grain yield production of soybean.

Sweet potato : Tuber yield of sweet potato was highest (252 q / ha) under sole cropping planted on the first date, and was significantly higher than those of the other treatments (Table 4.8). Due to intercropping, reduction in tuber yield was less (28 %) under 1 : 1 arrangement (rows 60 cm apart), when sweet potato was planted simultaneously (182 q / ha). The yield reduction was maximum (91 %) under 1 : 1 arrangement (rows 30 cm apart), when sweet potato was planted at 90 days after sowing of soybean (23 q / ha).

Table 4.8 Grain yield of soybean (kg / ha) and tuber yield of sweet potato (q / ha) : Experiment number 1a, b and c

Treatment	1977-78		1978-79		1979-80	
	S	SP	S	SP	S	SP
Sole S	2697		2211		2450	
SP planted at 0 DAS						
Sole SP		252.1		321.0		315.8
S/SP 1:1(rows at 30 cm)	2022	77.5	1790	255.0	1679	149.2
S/SP 1:1(rows at 60 cm)	1450	182.1	937	357.5	1123	330.0
S/SP 2:1(rows at 40 cm)	2183	116.3	1979	231.5	1600	164.6
S/SP 2:2(rows at 30 cm)	2180	97.1	1877	273.3	1561	220.6
SP planted at 45 DAS						
Sole SP		219.2		266.7		251.0
S/SP 1:1(rows at 30 cm)	2042	42.1	2058	148.3	2033	82.3
S/SP 1:1(rows at 60 cm)	1563	132.5	1050	217.7	1375	165.0
S/SP 2:1(rows at 40 cm)	2283	86.7	1929	158.5	1871	99.6
S/SP 2:2(rows at 30 cm)	2130	54.2	1983	213.8	1777	117.9
SP planted at 90 DAS						
Sole SP		147.5		177.9		145.8
S/SP 1:1(rows at 30 cm)	2083	23.3	1794	90.4	1723	101.7
S/SP 1:1(rows at 60 cm)	1588	95.0	1173	99.0	1461	103.5
S/SP 2:1(rows at 40 cm)	2030	52.9	1858	75.8	1862	88.3
S/SP 2:2(rows at 30 cm)	2233	39.6	1732	80.0	1779	87.1
S. Em ±	141.7	11.23	145.8	14.40	107.5	12.50
C. D. at 5 %	408.3	32.43	420.8	41.58	310.0	36.09
S.A. x T.P.	NS	*	NS	**	NS	**

Table 4.8 (continued)

Treatment	1977-78		1978-79		1979-80	
	S	SP	S	SP	S	SP
Spatial arrangement of sweet potato (S.A.)						
Sole SP		206.3		255.2		237.6
S/SP 1:1(rows at 30 cm)	2048	47.6	1881	164.6	1812	111.0
S/SP 1:1(rows at 60 cm)	1533	136.5	1053	224.7	1319	199.5
S/SP 2:1(rows at 40 cm)	2165	85.3	1922	155.3	1777	117.5
S/SP 2:2(rows at 30 cm)	2180	63.6	1864	189.0	1706	141.9
S. Em ±	81.7	6.48	84.2	8.31	61.7	7.22
C. D. at 5 %	235.0	18.72	243.3	23.99	178.3	20.83
Timing of planting of sweet potato (T.P.)						
0 DAS	1958	145.0	1646	287.7	1491	236.0
45 DAS	2005	106.9	1755	201.0	1764	143.2
90 DAS	1983	71.7	1639	104.6	1707	105.3
S. Em ±	71.7	5.03	73.3	6.44	53.3	5.59
C. D. at 5 %	NS	14.53	NS	18.60	154.2	16.14
C. V.	13.9	20.8	17.0	14.6	12.5	15.5

S = Soybean, SP = Sweet potato, DAS = Days after sowing of soybean,
NS = Not significant, * and ** = Significant at 5 % and 1 %,respectively

Spatial arrangements had significant effect on the tuber production (Table 4.8). The tuber yields were reduced by 34, 59, 69 and 77 %,respectively, under 1 : 1 (rows 60 cm apart),2 : 1, 2 : 2 (alternate paired rows) and 1 : 1 (rows 30 cm apart) soybean / sweet potato row arrangements as compared to the sole crop yield. Different dates of planting of sweet potato had significant effect on the tuber production. Tuber yields decreased gradually with late planting. The reductions were 26 and 51 %, respectively, when sweet potato was planted at 45 and 90 days after first planting.

Different spatial arrangements with sweet potato and their timings of planting had significant interaction effect on the tuber production (Table 4.8). Tuber yields did not decrease significantly in the plots planted at 90 days after sowing of soybean, as compared to those planted at 45 days after sowing of soybean under 1 : 1 (rows 30 cm apart) and 2 : 2 alternate paired row arrangements; whereas tuber yields were reduced due to late planting in all other situations.

4.1.3.2 Experiment number 1b (1978 - 79)

Soybean : During 1978 - 79 the soybean yield reduction due to intercropping was significant only under 1 : 1 arrangement (rows 60 cm apart) with sweet potato, planted at any date of planting and under 2 : 2 alternate paired row arrangement, where sweet potato was planted at 90 days after sowing of soybean (Table 4.8). The yield reductions under other intercropping treatments were not up to the level of significance, probably due to

comparatively low yield of soybean under sole cropping. The other effects were similar to those described in Experiment number 1a.

Sweet potato : The tuber yields (Table 4.8) varied under different cropping systems in the way, more or less, similar to that described in Experiment number 1a (1977 - 78) with the exception, that in the first date of planting 1 : 1 arrangement (rows 60 cm apart) produced tuber yield (358 q / ha) at par with that under sole cropping (321 q / ha). The high-yielding variety of sweet potato cv. H-268, used in this experiment, produced tuber yield much higher than the variety, used earlier.

Under different spatial arrangements, the mean tuber yields decreased by 12, 26, 36 and 39 %, respectively, under 1 : 1 (rows 60 cm apart), 2 : 2 alternate paired rows, 1 : 1 (rows 30 cm apart) and 2S : 1SP row arrangements as compared to the sole crop yield (Table 4.8). The last two arrangements were statistically at par. The effect of timings of planting of sweet potato was similar to that in Experiment number 1a.

The effect of interaction of different spatial arrangements with sweet potato and their timings of planting on tuber production was significant (Table 4.8). In the first date of planting, under 1 : 1 arrangement (rows 60 cm apart) the tuber yield of sweet potato was significantly higher than those under other row arrangements of intercropping, at second date of planting 1 : 1 arrangement (60 cm apart rows) had no difference with 2 : 2 (alternate paired rows) arrangement, and in the last date of planting of sweet potato, all the four row arrangements of intercropping recorded no yield differences among themselves.

4.1.3.3 Experiment number 1c (1979 - 80)

Soybean : The trend of variations in soybean yield during 1979 - 80 due to different intercropping systems (Table 4.8) was similar to those recorded in earlier experiments. Maximum (54 %) and minimum (17 %) yield reductions of soybean were obtained, respectively, under 1 : 1 arrangement (rows 60 cm apart) planted simultaneously and under 1 : 1 arrangement (rows 30 cm apart) with sweet potato planted at 45 days after sowing of soybean.

The effect of row arrangements on grain yield of soybean was similar to those stated in earlier experiments. Regarding the effect of timings of planting of sweet potato, relay planting increased the soybean yield significantly over that of simultaneous planting. This yield increase was 18 and 15 %, respectively, under second and third dates of planting of sweet potato.

Sweet potato : Tuber productions during 1979 - 80 (Table 4.8) due to different cropping treatments, spatial arrangements with sweet potato and their timings of planting showed similar trend of variations in tuber yield as described in Experiment number 1b.

The interaction of different row arrangements of sweet potato and their timings of planting was significant (Table 4.8) and the trend of variations was similar to that described in Experiment number 1a (1977 - 78); in this experiment, reduction in tuber yield at third date of planting as compared to that at second date of planting was not significant under 2S : 1SP row arrangement.

4.1.4 Aggressivity

Aggressivity (A) is a measure of how much the relative yield increase in species 'a' is greater than that for species 'b'. Aggressivity values of soybean, in combination with sweet potato (A_s) have been calculated and the mean values have been summarised in Table 4.9.

4.1.4.1 Experiment number 1a (1977 - 78)

It can be perused from Table 4.9 that among the 12 different situations of intercropping, soybean was dominated by sweet potato only in one case, i.e., under 1 : 1 row arrangement (rows 60 cm apart) when both the crops were established simultaneously, having Aggressivity (A_s) value of -0.37. In all other cases, soybean had positive values of Aggressivity, indicating the dominance of soybean over sweet potato. The degree of dominance of soybean crop varied under different treatments. Soybean crop had high degree of Aggressivity under 1 : 1 arrangement with rows 30 cm apart (1.36) and under 2 : 2 alternate paired rows (1.34) when sweet potato was planted at 90 days later than the sowing of soybean.

Among the four spatial arrangements, highest degree of Aggressivity of soybean (1.14) was recorded under 1 : 1 arrangement (rows 30 cm apart), followed by 2 : 2 alternate paired rows (1.11) and 2S : 1SP arrangement (0.70). In the other row arrangement of 1 : 1 (rows 60 cm apart), soybean failed to show any superiority and had the Aggressivity value of only 0.05. The variations in the mean Aggressivity values of soybean in respect of different

Table 4.9 Aggressivity of soybean (in combination with sweet potato): Experiment number 1a, b and c

Treatment	1977-78	1978-79	1979-80
SP planted at 0 DAS			
S/SP 1:1 (rows at 30 cm)	0.88	0.03	0.43
S/SP 1:1 (rows at 60 cm)	-0.37	-1.38	-1.17
S/SP 2:1 (rows at 40 cm)	0.52	0.26	0.20
S/SP 2:2 (rows at 30 cm)	0.85	-0.01	-0.12
SP planted at 45 DAS			
S/SP 1:1 (rows at 30 cm)	1.18	0.94	1.14
S/SP 1:1 (rows at 60 cm)	0.11	-0.41	0.08
S/SP 2:1((rows at 40 cm)	0.75	0.57	0.67
S/SP 2:2 (rows at 30 cm)	1.15	0.46	0.70
SP planted at 90 DAS			
S/SP 1:1 (rows at 30 cm)	1.36	1.06	0.76
S/SP 1:1 (rows at 60 cm)	0.42	0.45	0.54
S/SP 2:1 (rows at 40 cm)	0.81	0.91	0.72
S/SP 2:2 (rows at 30 cm)	1.34	1.07	0.90
Spatial arrangement with sweet potato			
S/SP 1:1 (rows at 30 cm)	1.14	0.68	0.78
S/SP 1:1 (rows at 60 cm)	0.05	-0.45	-0.19
S/SP 2:1 (rows at 40 cm)	0.70	0.58	0.53
S/SP 2:2 (rows at 30 cm)	1.11	0.51	0.49
Timing of planting of sweet potato			
0 DAS	0.47	-0.27	-0.17
45 DAS	0.80	0.39	0.65
90 DAS	0.99	0.87	0.73

S = Soybean, SP = Sweet potato, DAS = Days after sowing of soybean

dates of planting of sweet potato revealed that the dominance of soybean increased with delay in planting of sweet potato (Table 4.9).

4.1.4.2 Experiment number 1b (1978 - 79)

The trend of variations in Aggressivity values of soybean, during 1978 - 79, was similar to that observed in Experiment number 1a (Table 4.9). The values were, however, comparatively lower during 1978 - 79, most probably due to use of sweet potato cv. H-268 with yield potentiality higher than the local variety.

The mean Aggressivity value under 2S : 1SP arrangement (0.58) was slightly higher than that under 2 : 2 alternate paired rows arrangement (0.51). Under the 1 : 1 arrangement (rows 60 cm apart), soybean crop was dominated (A_s = -0.45) by sweet potato. The mean Aggressivity values of soybean under different dates of planting of sweet potato varied in the way similar to that in Experiment number 1a. During 1978 - 79, soybean was, however, dominated by sweet potato when planted simultaneously (A_s = -0.27).

4.1.4.3 Experiment number 1c (1979 - 80)

The results summarised in Table 4.9 indicated that the Aggressivity of soybean during 1979 - 80 differed in the way as mentioned in the earlier experiments. The highest Aggressivity value of soybean was recorded under 1 : 1 arrangement (rows 30 cm apart) with sweet potato planted at 45 days after sowing of

soybean (A_s = 1.14). The Aggressivity of sweet potato over soybean was very high (A_s = -1.17) under 1 : 1 arrangement (rows 60 cm apart),when both the crops were established simultaneously.

4.1.5 Land Equivalent Ratio

The Land Equivalent Ratio (LER) is the relative land area under sole crops that is required to produce the yields achieved under intercropping. The LER values of each of the two component crops, soybean and sweet potato and also for the combined intercrop yields, are summarised in Table 4.10. The LER values of sweet potato were calculated on the basis of tuber yield of sweet potato sole crop, planted at the time of sowing of soybean.

4.1.5.1 Experiment number 1a (1977 - 78)

Soybean : The LER values of soybean were reduced under intercropping situations (Table 4.10) as compared to that of soybean sole crop. The LER values of soybean were higher than 0.5 in all the intercropping treatments. Among the different intercropping treatments, highest value of LER (0.85) was recorded under 2S : 1SP arrangement (rows 40 cm apart) when sweet potato was planted at 45 days after sowing of soybean and the lowest value (0.54) under 1 : 1 arrangement (rows at 60 cm),when both the crops were established simultaneously.

Among the different spatial arrangements of intercropping (Table 4.10), 1 : 1 arrangement (rows 60 cm apart) showed low LER value of soybean (0.57). The LER values under the other three row arrangements were significantly higher than that of the earlier one,

Table 4.10 Land Equivalent Ratio for soybean, sweet potato and combined yields : Experiment number 1a, b and c

Treatment	1977-78			1978-79			1979-80		
	S	SP	Comb.	S	SP	Comb.	S	SP	Comb.
Sole S	1.00		1.00	1.00		1.00	1.00		1.00
SP planted at 0 DAS									
Sole SP		1.00	1.00		1.00	1.00		1.00	1.00
S/SP 1:1(rows at 30 cm)	0.75	0.31	1.06	0.81	0.80	1.61	0.69	0.47	1.16
S/SP 1:1(rows at 60 cm)	0.54	0.72	1.26	0.43	1.11	1.54	0.46	1.05	1.51
S/SP 2:1(rows at 40 cm)	0.81	0.46	1.27	0.90	0.72	1.62	0.65	0.52	1.17
S/SP 2:2(rows at 30 cm)	0.81	0.39	1.20	0.85	0.85	1.70	0.64	0.70	1.34
SP planted at 45 DAS									
Sole SP		0.87	0.87		0.83	0.83		0.80	0.80
S/SP 1:1(rows at 30 cm)	0.76	0.17	0.93	0.93	0.47	1.40	0.83	0.26	1.09
S/SP 1:1(rows at 60 cm)	0.58	0.53	1.11	0.47	0.68	1.15	0.56	0.52	1.08
S/SP 2:1(rows at 40 cm)	0.85	0.34	1.19	0.87	0.49	1.36	0.77	0.32	1.09
S/SP 2:2(rows at 30 cm)	0.79	0.21	1.00	0.90	0.66	1.56	0.73	0.38	1.11
SP planted at 90 DAS									
Sole SP		0.58	0.58		0.55	0.55		0.46	0.46
S/SP 1:1(rows at 30 cm)	0.77	0.10	0.87	0.81	0.28	1.09	0.71	0.32	1.03
S/SP 1:1(rows at 60 cm)	0.59	0.38	0.97	0.53	0.31	0.84	0.60	0.33	0.93
S/SP 2:1(rows at 40 cm)	0.75	0.21	0.96	0.84	0.24	1.08	0.76	0.28	1.04
S/SP 2:2(rows at 30 cm)	0.83	0.16	0.99	0.79	0.25	1.04	0.73	0.28	1.01
S. Em ±	0.053	0.045	0.070	0.066	0.045	0.073	0.044	0.040	0.056
C. D.at 5%	0.151	0.129	0.199	0.190	0.130	0.208	0.127	0.114	0.159
S.A. x T.P.	NS	*	NS	NS	**	NS	NS	**	**

Table 4.10 (continued)

Treatment	1977-78			1978-79			1979-80		
	S	SP	Comb.	S	SP	Comb.	S	SP	Comb.
Spatial arrangement with sweet potato (S.A.)									
Sole SP		0.82	0.82		0.79	0.79		0.75	0.75
S/SP 1:1 (rows at 30 cm)	0.76	0.19	0.95	0.85	0.51	1.36	0.74	0.35	1.09
S/SP 1:1 (rows at 60 cm)	0.57	0.54	1.11	0.48	0.70	1.18	0.54	0.63	1.17
S/SP 2:1 (rows at 40 cm)	0.80	0.34	1.14	0.87	0.48	1.35	0.73	0.37	1.10
S/SP 2:2 (rows at 30 cm)	0.81	0.25	1.06	0.84	0.59	1.43	0.70	0.45	1.15
S. Em ±	0.030	0.026	0.041	0.038	0.026	0.042	0.025	0.023	0.032
C. D. at 5%	0.087	0.074	0.117	0.110	0.075	0.119	0.073	0.066	0.091
Timing of planting of sweet potato (T.P.)									
0 DAS	0.72	0.58	1.16	0.74	0.90	1.49	0.61	0.75	1.24
45 DAS	0.74	0.42	1.02	0.79	0.63	1.26	0.72	0.45	1.03
90 DAS	0.74	0.28	0.87	0.74	0.33	0.92	0.70	0.33	0.89
S. Em ±	0.027	0.020	0.031	0.033	0.020	0.033	0.022	0.018	0.025
C. D. at 5%	NS	0.058	0.088	NS	0.058	0.094	0.063	0.051	0.071

S = Soybean, SP = Sweet potato, Comb. = Combined yields,
DAS = Days after sowing of soybean, NS = Not significant,
* and ** = Significant at 5 % and 1%,respectively

but the differences in LER values under those three row arrangements were statistically not significant. Different timings of planting of sweet potato had no effect on causing the differences in LER values of soybean.

Sweet potato : The maximum (0.72) and minimum (0.10) LER values of sweet potato were recorded under 1 : 1 arrangement (rows 60 cm apart) when both the crops were established simultaneously and under 1 : 1 arrangement (rows 30 cm apart) when sweet potato was planted at 90 days after sowing of soybean, respectively (Table 4.10).

The mean LER value of sweet potato was highest (0.82) in sole cropping (Table 4.10), followed by the intercroppings, 1 : 1 arrangement (rows 60 cm apart), 2S : 1SP, 2 : 2 alternate paired rows and 1 : 1 arrangement (rows 30 cm apart); the LER values under the last two arrangements did not differ significantly. The mean LER values of sweet potato decreased significantly with delay in planting of sweet potato.

The interaction effect of different timings of planting of sweet potato with their row arrangements was significant (Table 4.10) and indicated that the LER values of sweet potato planted at 90 days after sowing of soybean were not inferior to those, planted at 45 days after sowing of soybean under 1 : 1 (rows 30 cm apart) and 2 : 2 alternate paired row arrangements. Similarly, the value at the second date of planting of sweet potato was not inferior to that under simultaneous planting of crops in 2S : 1SP

arrangement. In all other cases, the values were reduced significantly with delayed plantings.

Total : From the LER values of the combined intercrop yields during 1977 - 78, presented in Table 4.10, it was observed that under 2S : 1SP, 1 : 1 (rows 60 cm apart) and 2 : 2 alternate paired row arrangements, when both the crops were planted simultaneously, the yield advantages to the tune of 20 to 27 % were obtained. Among the other intercroppings, the treatments 2S : 1SP, 1 : 1 (rows 60 cm apart) arrangements, when sweet potato was planted at 45 days after sowing of soybean, recorded 11 to 19 % yield advantages. When the LER values of combined intercrop yields in respect of different row arrangements of intercropping were compared with those of sweet potato sole croppings under respective dates of planting, most of the intercropping systems were found to be beneficial; the advantages were more with earlier plantings of sweet potato.

Different spatial arrangements of intercropping substantially increased the total LER values over the sole cropping of sweet potato (Table 4.10). Under the spatial arrangements, 2S : 1SP, 1 : 1 (60 cm apart rows), 2 : 2 (alternate paired rows) and 1 : 1 (rows 30 cm apart), the yield advantages were 39, 35, 29 and 16 %, respectively, over sole crop of sweet potato; the advantages in first three intercropping arrangements were, however, statistically not different. Total LER values decreased significantly with delay in planting of sweet potato.

4.1.5.2 Experiment number 1b (1978 - 79)

Soybean : The LER values of soybean during 1978 - 79 (Table 4.10) showed similar trend of variations, as has been described earlier in Experiment number 1a, with the difference that during 1978 - 79, the LER values of soybean were less than 0.5 under 1 : 1 arrangement (rows 60 cm apart), when sweet potato was planted simultaneously (0.43) and at 45 days after sowing of soybean (0.47). The highest value (0.93) was recorded under 1 : 1 arrangement (rows 30 cm apart) when sweet potato was planted at 45 days after the sowing of soybean.

Sweet potato : The trend of variations in the LER values of sweet potato during 1978 - 79 (Table 4.10) was very similar to that, described earlier in Experiment number 1a. The values were comparatively higher during 1978 - 79 than in 1977 - 78. Moreover, an yield advantage of 11 % over sole cropping was obtained under 1 : 1 arrangement (rows 60 cm apart), when both the crops were established simultaneously. In most of the cases, the values in different dates of planting were more than 50 % of the values of sole croppings, planted in the respective dates.

The mean LER values of sweet potato decreased significantly (Table 4.10) in the order, viz. sole cropping, 1 : 1 arrangement (rows 60 cm apart) and 2 : 2 alternate paired row arrangement. The other two arrangements did not show significant difference between them and had lower LER values than the earlier ones. The mean LER values of sweet potato decreased significantly with successive delay in planting of sweet potato.

The interaction effect of different row arrangements and timings of planting of sweet potato was significant (Table 4.10) and indicated that the LER value of sweet potato under 1 : 1 (rows 60 cm apart) arrangement was statistically at par at first date of planting and significantly lower at second and third dates of planting of sweet potato as compared to that under sole cropping.

Total : The LER values for the combined intercrop yields during 1978 - 79 were comparatively higher than those in 1977 - 78 (Table 4.10), probably due to use of high-yielding variety of sweet potato (cv. H-268). The yield advantages were fairly high (54 to 70 %) under simultaneous establishment of two crops.

The mean values of total LER indicated that under 2 : 2 alternate paired rows, 1 : 1 (rows 30 cm apart), 2S : 1SP, and 1 : 1 (rows 60 cm apart) row arrangements, yield advantages were 81, 73, 71 and 49 % respectively, over that of sole cropping. Timings of planting of sweet potato affected the total LER values in similar way, as was observed during 1977 - 78.

4.1.5.3 Experiment number 1c (1979 - 80)

Soybean : During 1979 - 80, the variation in the LER values of soybean (Table 4.10) was similar to that found in Experiment number 1b, with the following dissimilarities :

(i) The LER value of soybean was less than 0.5 only under 1 : 1 arrangement (rows 60 cm apart) when both crops were established simultaneously.

(ii) The effect of different timings of planting of sweet potato was significant; under relay plantings of sweet potato soybean had significantly higher LER values over that, recorded under simultaneous planting.

Sweet potato : The trend of variations in the LER values of sweet potato during 1979 - 80 (Table 4.10) was similar to those observed in earlier experiments. Under 1 : 1 arrangement (rows 60 cm apart) with simultaneous planting of both the crops, LER value was 5 % higher than that under sole cropping. The LER values of sweet potato were comparatively lower in 1979 - 80 than those recorded during 1978 - 79; the weather condition in 1978 - 79 might have favoured the growth of sweet potato.

Total : Maximum yield advantage (51 %) was obtained from 1 : 1 (rows 60 cm apart) arrangement, when both the crops were established simultaneously (Table 4.10).

The mean LER values for the combined intercrop yields were 56, 53, 47 and 45 % higher than the sole cropping under 1 : 1 (rows 60 cm apart), 2 : 2 (alternate paired rows), 2S : 1SP and 1 : 1 (rows 30 cm apart) row arrangements of intercropping, respectively. The mean LER values decreased with the delay in planting of sweet potato.

The interaction effect of different spatial arrangements and timings of planting of sweet potato was significant (Table 4.10) and indicated that the total LER values under 1 : 1 (rows 60 cm apart) and 2 : 2 alternate paired row arrangements were reduced

significantly at second date of planting of sweet potato as compared to those under simultaneous planting. In all other cases of intercropping arrangements, the values were not reduced significantly due to delay in planting of sweet potato.

4.1.6 Competitive Ratio

The Competitive Ratio (CR) is a measure of the degree of competition and indicates the number of times one crop is more competitive than the other. The Competitive Ratio (CR) values of the two crops are the reciprocals of each other (Table 4.11). For brevity the CR values of soybean are being mainly discussed here.

4.1.6.1 Experiment number 1a (1977 - 78)

The CR values of soybean crop, summarised in Table 4.11, indicated that the value was maximum (8.55) under 1 : 1 arrangement (rows 30 cm apart), when sweet potato crop was planted at 90 days after the sowing of soybean. Soybean crop was the least competitive (CR_s = 0.74), or in other words sweet potato was the most competitive (CR_{sp} = 1.38) under 1 : 1 arrangement (rows 60 cm apart), when the two crops were established simultaneously. Soybean crop was more competitive under 1 : 1 (rows 30 cm apart) and 2 : 2 (alternate paired rows) arrangements under all dates of planting of sweet potato.

The mean CR values indicated that soybean was the most competitive under 1 : 1 (rows 30 cm apart) arrangement (CR_s = 5.18), followed by 2 : 2 (alternate paired rows) arrangement (CR_s = 3.71).

Table 4.11 Competitive Ratio of soybean and sweet potato : Experiment number 1a, b and c

Treatment	1977-78		1978-79		1979-80	
	S	SP	S	SP	S	SP
SP planted at 0 DAS						
S/SP 1:1 (rows at 30 cm)	2.46	0.41	1.02	0.99	1.50	0.70
S/SP 1:1 (rows at 60 cm)	0.74	1.38	0.39	2.64	0.44	2.29
S/SP 2:1 (rows at 40 cm)	0.87	1.15	0.63	1.65	0.63	1.61
S/SP 2:2 (rows at 30 cm)	2.10	0.49	1.01	1.05	0.92	1.10
SP planted at 45 DAS						
S/SP 1:1 (rows at 30 cm)	4.53	0.22	2.01	0.51	3.28	0.31
S/SP 1:1 (rows at 60 cm)	1.10	0.91	0.71	1.47	1.11	0.95
S/SP 2:1 (rows at 40 cm)	1.26	0.82	0.89	1.20	1.26	0.84
S/SP 2:2 (rows at 30 cm)	3.75	0.27	1.44	0.77	1.99	0.52
SP planted at 90 DAS						
S/SP 1:1 (rows at 30 cm)	8.55	0.12	2.90	0.35	2.30	0.47
S/SP 1:1 (rows at 60 cm)	1.61	0.65	1.73	0.58	1.84	0.55
S/SP 2:1 (rows at 40 cm)	1.83	0.56	1.79	0.56	1.40	0.75
S/SP 2:2 (rows at 30 cm)	5.28	0.19	3.15	0.32	2.61	0.39
S. Em ±	0.377	0.047	0.140	0.135	0.182	0.074
C. D. at 5 %	1.085	0.135	0.403	0.389	0.524	0.213
S.A. x T.P.	**	**	**	**	**	**

Table 4.11 (continued)

Treatment	1977-78		1978-79		1979-80	
	S	SP	S	SP	S	SP
Spatial arrangement with sweet potato (S.A.)						
S/SP 1:1 (rows at 30 cm)	5.18	0.25	1.98	0.62	2.36	0.49
S/SP 1:1 (rows at 60 cm)	1.15	0.98	0.94	1.56	1.13	1.26
S/SP 2:1 (rows at 40 cm)	1.32	0.84	1.10	1.14	1.10	1.06
S/SP 2:2 (rows at 30 cm)	3.71	0.32	1.87	0.71	1.84	0.67
S. Em ±	0.218	0.027	0.081	0.078	0.105	0.043
C. D. at 5 %	0.628	0.078	0.233	0.225	0.302	0.124
Timing of planting of sweet potato (T.P.)						
0 DAS	1.54	0.86	0.76	1.58	0.87	1.42
45 DAS	2.66	0.56	1.26	0.99	1.91	0.65
90 DAS	4.31	0.38	2.39	0.45	2.03	0.54
S. Em ±	0.188	0.023	0.070	0.068	0.091	0.037
C. D. at 5 %	0.541	0.066	0.202	0.196	0.262	0.107

S = Soybean, SP = Sweet potato, DAS = Days after sowing of soybean,

** = Significant at 1 %

Soybean crop was less competitive under the other two arrangements. Competitive ability of soybean increased with the delay in planting of sweet potato.

The interaction effect of different timings of planting of sweet potato, with their spatial arrangements on the CR values of soybean, was significant (Table 4.11). The values increased significantly with the successive delay in planting of sweet potato under 1 : 1 (rows 30 cm apart) and 2 : 2 (alternate paired rows) arrangements. Whereas, under the other two methods of row arrangement, increase in the CR values was not significant up to the last date of planting of sweet potato.

4.1.6.2 Experiment number 1b (1978 - 79)

The trend of variations in CR values of soybean during 1978 - 79 (Table 4.11) was very similar to those, reported in 1977 - 78. The values were, however, lower in general as compared to those in earlier experiment. This was, probably, due to low yield potentiality of the sweet potato variety used in the Experiment number 1a.

Regarding the interaction effect, the CR values of soybean under 1 : 1 (rows 60 cm apart) and 2S : 1SP row arrangements did not increase appreciably when sweet potato was planted at 45 days after soybean over the simultaneous planting. In the other situations, the values increased significantly with the delay in planting of sweet potato (Table 4.11).

4.1.6.3 Experiment number 1c (1979 - 80)

The trend of variations in CR values of soybean (Table 4.11) was similar to those observed in Experiment number 1b, as described earlier.

Different row arrangements of intercropping and the timings of planting of sweet potato indicated interaction effect on the CR values of soybean (Table 4.11). Under 2S : 1SP arrangement, the CR values of soybean did not increase significantly at the third date of planting over the second date of planting of sweet potato. Under 1 : 1 (rows 30 cm apart) arrangement, the value decreased at the third date of planting as compared to that at second date of planting of sweet potato. The roots of soybean crop under 1 : 1 arrangement (rows 30 cm apart) was damaged during planting of sweet potato on the third date, which probably might have affected the grain yield and also the CR values of soybean. Under all other situations, the CR values increased appreciably with the delay in planting of sweet potato.

4.2 Growth, yield and competition function : Experiment number 2

The Experiment on 'Intercropping of soybean, maize and pigeonpea with sweet potato' was conducted with the objective to study the growth and yield performances of grain crops (soybean, maize and pigeonpea) and tuber crop (sweet potato) under sole and intercropping systems with different timings of planting of

sweet potato. The experiment was carried out for three years from 1978 - 79 to 1980 - 81 as per details, provided in the chapter on 'Materials and Methods'.

4.2.1 Dry matter accumulation

Dry matter production was studied at 4 stages in Experiment number 2c during the year 1980 - 81.

4.2.1.1 Soybean

The first sampling on dry matter accumulation was done at 72 days after sowing (DAS). The total dry matter accumulated in soybean shoot was maximum (480 g / m^2) under sole cropping (Table 4.12). Accumulation of dry matter was reduced appreciably due to intercropping. This reduction in dry matter of soybean was not only due to competition, but also due to lower number of soybean rows per unit area. Maximum reduction (61 %) in shoot dry matter was recorded when soybean was intercropped with sweet potato cv. Pusa Safed, planted simultaneously. The reduction was comparatively less (46 %) when soybean was intercropped with relay planted sweet potato cv. H-268.

The varieties of sweet potato affected dry matter accumulation in soybean (Table 4.12) similarly. A delay (90 days) in planting of sweet potato increased the soybean dry matter by 25 % over simultaneous planting.

Table 4.12 Dry matter accumulation in soybean (g / m^2) at 72 DAS : Experiment number 2c (1980 - 81)

Treatment	Dry wt. (g/m^2)
Sole soybean	480.4
Soybean/sweet potato cv. H-268 : 0 DAS	216.8
Soybean/sweet potato cv. H-268 : 90 DAS	260.7
Soybean/sweet potato cv. Pusa Safed : 0 DAS	185.5
Soybean/sweet potato cv. Pusa Safed : 90 DAS	242.1
S. Em ±	20.91
C. D. at 5 %	64.43
Sweet potato variety	
cv. H-268	238.8
cv. Pusa Safed	213.8
S. Em ±	14.79
C. D. at 5 %	NS
Timing of planting of sweet potato	
0 DAS of soybean	201.2
90 DAS of soybean	251.4
S. Em ±	14.79
C. D. at 5 %	45.57

DAS = Days after sowing of soybean,
NS = Not significant

4.2.1.2 Maize

Total dry matter accumulated in maize, sampled at 72 DAS (Table 4.13), was reduced (17 %) significantly only under simultaneously established maize / sweet potato (cv. Pusa Safed) intercropping as compared to sole cropping of maize (793 g / m^2). Dry matter accumulation in maize under other intercropping situations did not show wide differences with sole cropping.

Varieties of sweet potato did not cause wide differences in dry matter production of maize when planted as a component crop. When sweet potato was planted 90 days later than maize, dry matter in maize increased by 21 % over the treatment where both were established simultaneously (Table 4.13).

4.2.1.3 Pigeonpea

At 72 DAS, the different intercropping systems did not differ from sole cropping in respect of dry matter accumulation in pigeonpea (Table 4.14). Dry matter production was reduced in pigeonpea, when it was grown in association with sweet potato, established simultaneously, on and from 141 days after sowing. The reduction varied from 18 to 25 % as compared to the growth under sole cropping of pigeonpea. The effect of two competitive varieties of sweet potato on the growth of pigeonpea was very similar. The growth of pigeonpea plants was least affected when sweet potato was relay planted.

Table 4.13 Dry matter accumulation in maize (g / m^2) at 72 DAS : Experiment number 2c (1980 - 81)

Treatment	Dry wt (g/m^2)
Sole maize	793.2
Maize / sweet potato cv. H-268 : 0 DAS	697.3
Maize / sweet potato cv. H-268 : 90 DAS	836.5
Maize / sweet potato cv. Pusa Safed : 0 DAS	662.2
Maize / sweet potato cv. Pusa Safed : 90 DAS	812.3
S. Em ±	38.76
C. D. at 5 %	119.42
Sweet potato variety	
cv. H-268	766.9
cv. Pusa Safed	737.3
S. Em ±	27.41
C. D. at 5 %	NS
Timing of planting of sweet potato	
0 DAS of maize	679.8
90 DAS of maize	824.4
S. Em ±	27.41
C. D. at 5 %	84.45

DAS = Days after sowing of maize,
NS = Not significant

Table 4.14 Dry matter accumulation in pigeonpea (g / m^2 : Experiment number 2c (1980 - 81)

Treatment	72 DAS	141 DAS	197 DAS	244 DAS
Sole pigeonpea	86.7	405.6	694.9	1105.9
Pigeonpea/SP_1 : 0 DAS	81.0	312.1	566.8	858.3
Pigeonpea/SP_1 : 90 DAS	88.6	399.7	714.2	1141.7
Pigeonpea/SP_2 : 0 DAS	80.1	307.3	551.9	832.9
Pigeonpea/SP_2 : 90 DAS	89.2	382.5	710.4	1101.3
S. Em ±	6.07	7.56	14.96	62.53
C. D. at 5 %	NS	23.29	46.09	192.66
Variety of sweet potato				
SP_1 = cv. H-268	84.8	355.9	640.5	1000.0
SP_2 = cv. Pusa Safed	84.7	344.9	631.2	967.1
S. Em ±	4.29	5.34	10.58	44.21
C. D. at 5 %	NS	NS	NS	NS
Timing of planting of sweet potato				
0 DAS of pigeonpea	80.6	309.7	559.4	845.6
90 DAS of pigeonpea	88.9	391.1	712.3	1121.5
S. Em ±	4.29	5.34	10.58	44.21
C. D. at 5%	NS	16.45	32.60	136.22

DAS = Days after sowing of pigeonpea, NS = Not significant

4.2.1.4 Sweet potato

Leaf : Leaf dry weight of sweet potato, when planted along with the grain crops, increased up to 197 days and decreased afterwards (Table 4.15) in all cases, except under pigeonpea / sweet potato intercropping. When sweet potato was planted at 90 days after first date of planting, the leaf growth increased up to last date of sampling (244 DAS). The dry matter accumulation in leaf of both the varieties of sweet potato, when simultaneously grown in association with pigeonpea, was high at 72 DAS but decreased later on. Leaves of sweet potato cv. H-268 showed better initial growth, as recorded at 72 DAS, than cv. Pusa Safed. Later on, this difference between the varieties was reduced. Sweet potato leaves accumulated more dry matter under intercropping than under sole cropping with the passage of time, except when intercropped with pigeonpea, where there was appreciable reduction in leaf growth. Maize as companion crop favoured leaf growth of sweet potato more than that of soybean.

A delay of 90 days in planting of sweet potato reduced leaf dry matter accumulation by 96 and 61 % at 141 and 197 DAS, respectively. But at 244 DAS, 22 % higher leaf dry matter was recorded under late planting than under early planting.

Interaction effect of varieties of sweet potato and their timings of planting on dry matter accumulation in leaf was found to be significant at the third and the fourth dates of sampling (Table 4.16). Under the first date of planting, cv. H-268 accumulated more leaf dry matter than cv. Pusa Safed. But when planting was delayed by 90 days, better leaf growth was recorded in P. Safed.

Table 4.15 Dry matter accumulation in sweet potato leaf (g / m^2) : Experiment number 2c (1980 - 81)

Treatment	72 DAS	141 DAS	197 DAS	244 DAS
SP planted at 0 DAS				
Sole SP_1	101.4	162.6	186.8	106.8
Soybean / SP_1	112.0	205.4	225.0	123.8
Maize / SP_1	124.0	252.8	278.0	140.0
Pigeonpea / SP_1	139.0	93.2	75.2	61.3
SP planted at 90 DAS				
Sole SP_1		4.4	35.5	101.3
Soybean / SP_1		6.4	43.0	117.0
Maize / SP_1		5.6	59.3	157.5
Pigeonpea / SP_1		3.2	14.7	18.8
SP planted at 0 DAS				
Sole SP_2	68.4	148.0	109.8	59.2
Soybean / SP_2	72.0	180.2	171.8	70.3
Maize / SP_2	94.2	227.2	209.0	103.8
Pigeonpea / SP_2	93.0	104.2	79.0	42.5
SP planted at 90 DAS				
Sole SP_2		7.6	84.0	103.5
Soybean / SP_2		10.8	107.3	149.0
Maize / SP_2		14.2	143.3	164.3
Pigeonpea / SP_2		6.8	38.0	50.5
S. Em ±	4.73	11.87	13.32	12.75
C. D. at 5 %	13.91	33.84	37.97	36.34

Table 4.15 (continued)

Treatment	72 DAS	141 DAS	197 DAS	244 DAS
Sweet potato variety				
SP_1 = H-268	119.1	91.7	114.7	103.3
SP_2 = Pusa Safed	81.9	87.4	117.8	92.9
S. Em ±	2.37	4.20	4.71	4.51
C. D. at 5 %	6.97	NS	NS	NS
Cropping with sweet potato				
Sole sweet potato	84.9	80.7	104.0	92.7
Soybean / sweet potato	92.0	100.7	136.8	115.0
Maize / sweet potato	109.1	125.0	172.4	141.4
Pigeonpea / sweet potato	116.0	51.9	51.7	43.3
S. Em ±	3.35	5.93	6.66	6.37
C. D. at 5 %	9.85	16.90	18.99	18.16
Timing of planting of sweet potato				
0 DAS		171.7	166.8	88.5
90 DAS		7.4	65.6	107.7
S. Em ±		4.20	4.71	4.51
C. D. at 5 %		11.97	13.43	12.86

DAS = Days after sowing of grain crops

NS = Not significant

Table 4.16 Interaction effect of sweet potato varieties and their timings of planting on dry matter accumulation in sweet potato leaf (g / m^2) : Experiment number 2c (1980 - 81)

Timing of planting	At 197 DAS Variety		At 244 DAS Variety	
	H-268	Pusa Safed	H-268	Pusa Safed
0 DAS	191.3	142.4	108.0	69.0
90 DAS	38.1	93.2	98.7	116.8
S. Em ±	6.66		6.37	
C. D. at 5 %	18.99		18.16	

DAS = Days after sowing of grain crops

Different cropping systems with sweet potato and their timings of planting also showed significant interaction effect on leaf dry matter production at 141, 197 and 244 days stage (Table 4.17). At the early stage, differences in leaf dry matter under different croppings were more prominent in case of early planting of sweet potato, but in the case of late planting there was little difference. With the advancement of growing season, the differences among different croppings were reduced under simultaneous planting situation, whereas the differences increased under late planting.

Stem : Dry matter accumulation in sweet potato stem, when established simultaneously with grain crops, increased up to 197 days after planting and remained, more or less, constant

Table 4.17 Interaction effect of different croppings with sweet potato and their timings of planting on dry matter accumulation in sweet potato leaf (g / m^2) : Experiment number 2c (1980 - 81)

Cropping	Timing of planting	
	0 DAS	90 DAS
At 141 DAS		
Sole sweet potato	155.3	6.0
Soybean / sweet potato	192.8	8.6
Maize / sweet potato	240.0	9.9
Pigeonpea / sweet potato	98.7	5.0
S. Em ±	8.39	
C. D. at 5 %	23.92	
At 197 DAS		
Sole sweet potato	148.3	59.8
Soybean / sweet potato	198.4	75.2
Maize / sweet potato	243.5	101.3
Pigeonpea / sweet potato	77.1	26.4
S. Em ±	9.42	
C. D. at 5 %	26.85	
At 244 DAS		
Sole sweet potato	83.0	102.4
Soybean / sweet potato	97.1	133.0
Maize / sweet potato	121.9	160.9
Pigeonpea / sweet potato	51.9	34.7
S. Em ±	9.01	
C. D. at 5 %	25.68	

DAS = Days after sowing of grain crops

afterwards (Table 4.18). Under late planting, the stem growth continued to increase up to the end of crop season. Under simultaneous planting of maize / sweet potato intercropping, sweet potato accumulated 29 to 58 % more dry matter in cv. H-268 and 38 to 42 % more in cv. Pusa Safed over those of respective sole croppings. In soybean / sweet potato intercropping also, dry matter accumulation in sweet potato stem was more than under sole cropping. The extent of increase was 15 to 23 % in cv. H-268 and 3 to 11 % in cv. Pusa Safed over the respective sole crops. Stem growth of sweet potato, planted simultaneously within pigeonpea rows, was superior up to 72 days, when pigeonpea plants were small. Afterwards pigeonpea started to grow vigorously and stem growth of sweet potato was reduced (18 to 48 % in cv. H-268 and 28 to 33 % in cv. Pusa Safed). The extent of reduction increased with the advancement of growing period.

Pusa Safed variety of sweet potato accumulated about 42 % less dry matter in stem than that of cv. H-268 at 72 and 141 days after the first planting (Table 4.18). Dry matter production in the stem of two varieties had little difference at the last date of sampling.

Varieties of sweet potato and their timings of planting had significant interaction effect on dry matter accumulation in sweet potato stem at the second, third and fourth dates of sampling. Dry matter accumulation in sweet potato stem of H-268 variety was superior to cv. Pusa Safed under early planting situation during the second, third and fourth dates of sampling.

Table 4.18 Dry matter accumulation in sweet potato stem (g / m^2) : Experiment number 2c (1980 - 81)

Treatment	72 DAS	141 DAS	197 DAS	244 DAS
SP planted at 0 DAS				
Sole SP_1	161.8	247.6	351.3	347.5
Soybean / SP_1	199.0	294.8	403.3	400.0
Maize / SP_1	255.8	318.6	462.0	447.5
Pigeonpea / SP_1	199.0	203.6	210.5	182.5
SP planted at 90 DAS				
Sole SP_1		5.8	15.5	185.0
Soybean / SP_1		7.0	19.8	257.5
Maize / SP_1		7.2	31.5	355.0
Pigeonpea / SP_1		3.2	8.0	50.0
SP planted at 0 DAS				
Sole SP_2	99.2	145.0	258.0	252.5
Soybean / SP_2	102.4	158.8	287.0	275.0
Maize / SP_2	141.2	185.8	361.3	347.5
Pigeonpea / SP_2	132.8	105.0	183.0	170.0
SP planted at 90 DAS				
Sole SP_2		4.0	40.5	230.0
Soybean / SP_2		6.4	63.0	365.0
Maize / SP_2		10.0	81.0	412.3
Pigeonpea / SP_2		7.0	14.5	110.0
S. Em ±	8.20	9.79	10.08	13.39
C. D. at 5 %	24.12	27.91	28.73	38.17

Table 4.18 (continued)

Treatment	72 DAS	141 DAS	197 DAS	244 DAS
Sweet potato variety				
SP_1 = cv. H-268	203.9	136.0	187.7	278.1
SP_2 = cv. Pusa Safed	118.9	77.8	161.0	270.3
S. Em ±	4.10	3.46	3.57	4.73
C. D. at 5 %	12.06	9.86	10.18	NS
Cropping with sweet potato				
Sole sweet potato	130.5	100.6	166.3	253.8
Soybean / sweet potato	150.7	116.8	193.3	324.4
Maize / sweet potato	198.5	130.4	234.0	390.6
Pigeonpea / sweet potato	165.9	79.7	104.0	128.1
S. Em ±	5.80	4.89	5.04	6.69
C. D. at 5 %	17.06	13.94	14.37	19.07
Timing of planting of sweet potato				
0 DAS		207.4	314.6	302.8
90 DAS		6.3	34.2	245.6
S. Em ±		3.46	3.57	4.73
C. D. at 5 %		9.86	10.18	13.48

DAS = Days after sowing of grain crops

NS = Not significant

But under the situation of late planting of sweet potato, cv. H-268 failed to be superior at 141 days and proved to be inferior to cv. Pusa Safed during the subsequent growth period (Table 4.19).

Table 4.19 Interaction effect of sweet potato varieties and their timings of planting on dry matter accumulation in sweet potato stem (g / m^2) : Experiment number 2c (1980 - 81)

Variety	Timing of planting	
	0 DAS	90 DAS
At 141 DAS		
H-268	266.2	5.8
Pusa Safed	148.7	6.9
S. Em ±	4.89	
C. D. at 5 %	13.94	
At 197 DAS		
H-268	356.8	18.7
Pusa Safed	272.3	49.8
S. Em ±	5.04	
C. D. at 5 %	14.37	
At 244 DAS		
H-268	344.4	211.9
Pusa Safed	261.3	279.3
S. Em ±	6.69	
C. D. at 5 %	19.07	

DAS = Days after sowing of grain crops

Different cropping systems with sweet potato and their timings of planting also exhibited interaction effect on stem dry matter production at 141, 197 and 244 days (Table 4.20). Dry matter accumulation in sweet potato stem at 141 and 197 DAS under different cropping systems varied widely, when the component crops were established simultaneously, but not when sweet potato was relay planted. At 244 DAS, stem growth of late planted sweet potato increased and became equal to that of early planting under soybean / sweet potato and maize / sweet potato intercroppings. Whereas, growth of late planted sweet potato did not increase so much and remained far below the level of early planting under pigeonpea / sweet potato intercropping.

Tuber : Dry matter accumulation in sweet potato tuber (Table 4.21) under maize / sweet potato and soybean / sweet potato intercroppings were 14 to 29 % and 6 to 8 % higher over sole cropping of sweet potato cv. H-268, respectively; the differences were slightly high with cv. Pusa Safed. Maximum tuber dry weight was obtained under maize / sweet potato intercropping at 244 DAS (in cv. H-268 - 776 g / m^2 and in cv. Pusa Safed - 908 g / m^2). As compared to sole cropping, dry matter accumulation in sweet potato tuber under pigeonpea / sweet potato intercropping decreased by 13 to 71 %; the extent of reduction being high with the increase in age. Under simultaneous planting, all cropping systems, except pigeonpea / sweet potato intercropping, showed maximum rate of tuber bulking during the period from 142 to 197 DAS. Sweet potato, grown in association with maize, accumulated tuber dry matter at

Table 4.20 Interaction effect of different croppings with sweet potato and their timings of planting on dry matter accumulation in sweet potato stem (g / m^2) : Experiment number 2c (1980 - 81)

Cropping	Timing of planting	
	0 DAS	90 DAS
At 141 DAS		
Sole sweet potato	196.3	4.9
Soybean / sweet potato	226.8	6.7
Maize / sweet potato	252.2	8.6
Pigeonpea / sweet potato	154.3	5.1
S. Em ±	6.92	
C. D. at 5 %	19.73	
At 197 DAS		
Sole sweet potato	304.7	28.0
Soybean / sweet potato	345.2	41.4
Maize / sweet potato	411.7	56.3
Pigeonpea / sweet potato	196.8	11.3
S. Em ±	7.13	
C. D. at 5 %	20.32	
At 244 DAS		
Sole sweet potato	300.0	207.5
Soybean / sweet potato	337.5	311.3
Maize / sweet potato	397.5	383.6
Pigeonpea / sweet potato	176.3	80.0
S. Em ±	9.47	
C. D. at 5 %	27.00	

DAS = Days after sowing of grain crops

Table 4.21 Dry matter accumulation in sweet potato tuber (g / m^2) : Experiment number 2c (1980 - 81)

Treatment	72 DAS	141 DAS	197 DAS	244 DAS
SP planted at 0 DAS				
Sole SP_1	29.0	305.9	536.0	600.0
Soybean / SP_1	31.0	323.9	574.4	650.0
Maize / SP_1	33.0	354.7	668.8	776.0
Pigeonpea	24.0	244.8	270.1	189.0
SP planted at 90 DAS				
Sole SP_1			2.0	239.0
Soybean / SP_1			5.3	243.0
Maize / SP_1		1.0	28.0	313.0
Pigeonpea / SP_1			1.0	5.0
SP planted at 0 DAS				
Sole SP_2	9.6	322.3	693.0	765.0
Soybean / SP_2	10.8	358.4	735.1	795.0
Maize / SP_2	15.8	386.1	815.4	908.0
Pigeonpea / SP_2	8.4	268.8	333.9	226.0
SP planted at 90 DAS				
Sole SP_2			38.3	350.0
Soybean / SP_2			32.0	376.0
Maize / SP_2		0.5	72.4	469.0
Pigeonpea / SP_2			6.7	44.0
S. Em ±	2.32	9.06	13.09	21.02
C. D. at 5 %	6.82	26.29	37.31	59.92

Table 4.21 (continued)

Treatment	72 DAS	141 DAS	197 DAS	244 DAS
Sweet potato variety				
SP_1 = cv. H-268	29.3	307.3	260.7	376.9
SP_2 = Pusa Safed	11.2	333.9	340.9	491.6
S. Em ±	1.16	4.53	4.63	7.43
C. D. at 5 %	3.41	13.14	13.20	21.18
Cropping with sweet potato				
Sole sweet potato	19.3	314.1	317.3	488.5
Soybean / Sweet potato	20.9	341.2	336.7	516.0
Maize / sweet potato	24.4	370.4	396.2	616.5
Pigeonpea / sweet potato	16.2	256.8	152.9	116.0
S. Em ±	1.64	6.41	6.54	10.51
C. D. at 5 %	4.82	18.60	18.64	29.96
Timing of planting of sweet potato				
0 DAS			578.3	613.6
90 DAS			23.2	254.9
S. Em ±			4.63	7.43
C. D. at 5 %			13.20	21.18

DAS = Days after sowing of grain crops

the rate of 5.6 and 7.7 g / m^2 / day, with cv. H-268 and Pusa Safed, respectively, during this period.

The mean tuber dry weight (Table 4.21) was lower (62 %) in cv. Pusa Safed than that of cv. H-268 at the early stage (72 DAS). But the situation was reverse afterwords and Pusa Safed variety accumulated 9 to 31 % higher tuber dry matter than that of cv. H-268.

The interaction effect of varieties of sweet potato with different cropping systems at 244 DAS (Table 4.22) was significant. Pusa Safed variety proved to be superior to cv. H-268 in accumulating tuber dry matter under all cropping systems, except in the pigeonpea / sweet potato intercropping; here both the varieties behaved similarly.

Table 4.22 Interaction effect of sweet potato varieties and their different croppings on dry matter accumulation in sweet potato tuber (g/m^2) at 244 DAS : Experiment number 2c (1980 - 81)

Cropping	Variety	
	H-268	Pusa Safed
Sole sweet potato	419.5	557.5
Soybean / sweet potato	446.5	585.5
Maize / sweet potato	544.5	688.5
Pigeonpea / sweet potato	97.0	135.0
S. Em ±	14.87	
C. D. at 5 %	42.39	

Total : Total (shoot + tuber) dry matter accumulation in sweet potato plant was maximum throughout the growth period in maize / sweet potato intercropping, followed by soybean / sweet potato intercropping, sole cropping and pigeonpea / sweet potato intercropping under simultaneous planting situation (Table 4.23). Sweet potato, when grown in combination with maize and soybean, produced about 26 to 42 % and 5 to 17 % higher total dry matter, respectively, over those of sole cropping. Dry matter production, on the other hand, was reduced (22 to 59 %) under pigeonpea / sweet potato intercropping as compared to those of sole crop of sweet potato. Total dry matter accumulated in sweet potato plant increased up to 197 DAS and tended to decline subsequently. In maize / sweet potato intercropping under simultaneous planting, cv. H-268 and Pusa Safed accumulated 1409 and 1386 g / m^2 of dry matter, respectively, during that time. The rate of dry matter production was highest during the period from 142 to 197 days. Under maize / sweet potato intercropping the rate of total dry matter accumulation in sweet potato was 8.6 g / m^2 / day in cv. H-268 and 10.5 g / m^2 / day in cv. Pusa Safed, when the component crops were established simultaneously. A delay of 90 days in planting of sweet potato reduced the total dry matter production by 98, 88 and 40 % at 141, 197 and 244 DAS, respectively, as compared to under simultaneous planting.

The interaction effect of varieties of sweet potato with their timings of planting was significant at 141, 197 and 244 DAS (Table 4.24). Sweet potato cv. H-268 accumulated more total dry matter than cv. Pusa Safed under simultaneous planting, but there

Table 4.23 Total dry matter accumulation in sweet potato (g / m^2) : Experiment number 2c (1980 - 81)

Treatment	72 DAS	141 DAS	197 DAS	244 DAS
SP planted at 0 DAS				
Sole SP_1	292.2	716.1	1074.1	1054.3
Soybean / SP_1	342.0	824.1	1202.7	1173.8
Maize / SP_1	412.8	926.1	1408.8	1363.5
Pigeonpea / SP_1	362.0	541.6	555.8	432.8
SP planted at 90 DAS				
Sole SP_1		10.2	53.0	525.3
Soybean / SP_1		13.4	68.1	617.5
Maize / SP_1		13.8	118.8	825.5
Pigeonpea / SP_1		6.4	23.7	73.8
SP planted at 0 DAS				
Sole SP_2	177.2	615.3	1060.8	1076.7
Soybean / SP_2	185.2	697.4	1193.9	1140.3
Maize / SP_2	251.2	799.1	1385.7	1359.3
Pigeonpea / SP_2	234.2	478.0	595.9	438.5
SP planted at 90 DAS				
Sole SP_2		11.6	162.8	683.5
Soybean / SP_2		17.2	202.3	890.0
Maize / SP_2		24.7	296.7	1045.6
Pigeonpea / SP_2		13.8	59.2	204.5
S. Em ±	9.21	22.44	25.85	27.01
C. D. at 5 %	27.09	63.97	73.69	77.00

Table 4.23 (continued)

Treatment	72 DAS	141 DAS	197 DAS	244 DAS
Sweet potato variety				
SP_1 = cv. H-268	352.3	381.5	563.1	758.3
SP_2 = cv. Pusa Safed	212.0	332.1	619.7	854.8
S. Em ±	4.61	7.93	9.14	9.55
C. D. at 5 %	13.56	22.61	26.05	27.22
Cropping with sweet potato				
Sole sweet potato	234.7	338.3	587.7	835.0
Soybean/sweet potato	263.6	388.0	666.8	955.4
Maize / sweet potato	332.0	440.9	802.5	1148.5
Pigeonpea / sweet potato	298.1	260.0	308.7	287.4
S. Em ±	6.52	11.22	12.93	13.51
C. D. at 5 %	19.18	31.98	36.86	38.51
Timing of planting of sweet potato				
0 DAS		699.7	1059.7	1004.9
90 DAS		13.9	123.1	608.2
S. Em ±		7.93	9.14	9.55
C. D. at 5 %		22.61	26.05	27.22

DAS = Days after sowing of grain crops

was little difference between the varieties under late planting at 141 DAS. At 197 and 244 DAS two varieties were at par under early planting. But when planted at 90 days after first planting, cv. Pusa Safed produced comparatively more total dry matter than cv. H-268.

Table 4.24 Interaction effect of sweet potato varieties and their timings of planting on total dry matter accumulation in sweet potato (g / m^2) : Experiment number 2c (1980 - 81)

Variety	Timing of planting	
	0 DAS	90 DAS
At 141 DAS		
H-268	752.0	11.0
Pusa Safed	647.5	16.8
S. Em ±	11.22	
C. D. at 5 %	31.98	
At 197 DAS		
H-268	1060.4	65.9
Pusa Safed	1059.1	180.3
S. Em ±	12.93	
C. D. at 5 %	36.86	
At 244 DAS		
H-268	1006.1	510.5
Pusa Safed	1003.7	705.9
S. Em ±	13.51	
C. D. at 5 %	38.51	

DAS = Days after sowing of grain crops

The interaction effect of different croppings with sweet potato and their timings of planting on total dry matter production in sweet potato was found to be significant at 141 DAS (Table 4.25). Total dry matter accumulated in sweet potato varied significantly due to different croppings, when they were planted simultaneously. But when planting was delayed by 90 days, differences in dry matter accumulation under different cropping systems were low.

Table 4.25 Interaction effect of different croppings with sweet potato and their timings of planting on total dry matter accumulation in sweet potato (g / m^2) at 141 DAS : Experiment number 2c (1980 - 81)

Cropping	Timing of planting	
	0 DAS	90 DAS
Sole sweet potato	665.7	10.9
Soybean / sweet potato	760.8	15.3
Maize / sweet potato	862.6	19.3
Pigeonpea / sweet potato	509.8	10.1
S. Em ±	15.87	
C. D. at 5 %	45.24	

DAS = Days after sowing of grain crops

4.2.2 Light interception

4.2.2.1 Experiment number 2a (1978 - 79)

When sweet potato was planted simultaneously with the grain crops, the percentage light intercepted by sweet potato crop canopy increased up to 150 DAS; the values continued to increase up to 236 DAS, when sweet potato was relay planted (Table 4.26).

Table 4.26 Percent light interception by sweet potato : Experiment number 2a (1978 - 79)

Treatment	77 DAS	99 DAS	150 DAS	167 DAS	194 DAS	236 DAS
SP planted at 0 DAS						
Sole SP	75.4	87.1	93.6	92.5	90.0	90.1
Soybea / SP	78.5	69.7	94.7	93.0	91.9	91.3
Maize / SP	54.4	77.6	96.5	95.7	92.9	93.6
Pigeonpea / SP	58.1	32.2	14.6	10.5	5.2	18.5
SP planted at 45 DAS						
Sole SP	50.0	67.6	82.1	84.9	88.1	89.1
Soybean / SP	40.0	33.8	66.1	75.6	82.7	84.1
Maize / SP	19.3	47.8	76.8	83.6	89.7	90.7
Pigeonpea / SP	40.4	24.3	12.9	9.2	4.6	22.8
SP planted at 90 DAS						
Sole SP			40.2	51.9	68.7	75.3
Soybean / SP			41.2	50.0	66.4	72.1
Maize / SP			40.6	56.9	73.1	76.4
Pigeonpea / SP			8.0	5.4	2.3	15.1
S. Em ±	3.92	3.58	2.99	2.61	4.12	3.07
C. D. at 5 %	11.53	10.53	8.63	7.54	11.90	8.86
C. x T.P.	NS	NS	**	**	NS	NS
Cropping with sweet potato (C.)						
Sole SP	62.7	77.4	72.0	76.4	82.3	84.8
Soybean / SP	59.3	51.8	67.3	72.9	80.3	82.5
Maize / SP	36.9	62.7	71.3	78.7	85.3	86.9
Pigeonpea / SP	49.3	33.3	14.2	9.0	4.0	18.8
S. Em ±	2.78	2.53	1.73	1.51	2.38	1.77
C. D. at 5 %	8.18	7.44	5.00	4.36	6.87	5.11
Timing of planting of sweet potato (T.P.)						
0 DAS	66.6	67.7	76.6	73.4	70.0	73.4
45 DAS	37.4	43.4	59.5	63.3	66.3	71.7
90 DAS			32.5	41.1	52.6	59.7
S. Em ±	1.96	1.79	1.50	1.31	2.06	1.54
C. D. at 5 %	5.76	5.26	4.33	3.78	5.95	4.45

SP = Sweet potato, DAS = Days after sowing of grain crops,
NS = Not significant, ** = Significant at 1 %

Light interception by sweet potato, when intercropped with pigeonpea, decreased up to 194 DAS. At 236 DAS, the values were slightly higher than those at 194 DAS; this might be due to fall of leaves of pigeonpea with the advancement in age.

Sweet potato crop grown in association with soybean, recorded lower interception of light till soybean was harvested. Similarly, sweet potato intercropped with maize intercepted solar radiation less than those under sole crop of sweet potato, till about 90 days after maize sowing. After the harvest of maize at 95 DAS and the harvest of soybean at 115 DAS, the light interception by sweet potato canopy gradually increased up to 150 DAS and then maintained it till harvest of sweet potato crop.

The mean values of light interception percentages under different croppings (Table 4.26) indicated that sweet potato crop, when intercropped with maize or soybean, intercepted light less than that under sole cropping up to 99 DAS, but afterwards the light interception by sweet potato under soybean / sweet potato or maize / sweet potato intercropping was statistically at par with those under sole cropping. Interception of solar radiation by sweet potato under pigeonpea / sweet potato intercropping was not significantly lower than those under soybean / sweet potato intercropping at initial stage (77 DAS) but decreased severely afterwards (4 % interception at 194 DAS).

Light interception by sweet potato, when planted at 45 days after first date of planting, was always lower than that

under simultaneous planting, but the differences were not significant at 194 and 236 DAS (Table 4.26). Percentage interception under the third date of planting of sweet potato was reduced significantly throughout the growing period as compared to those under the first and second dates of planting of sweet potato; this is because at later planting the canopy of sweet potato was not as much developed as those in the early planted crop of sweet potato.

Interaction effect of different croppings with timings of planting of sweet potato was significant at 150 and 167 DAS (Table 4.26); when both soybean and maize were harvested and not competing with sweet potato. It indicated that light interception by sweet potato, planted at 45 DAS under soybean / sweet potato intercropping was significantly lower than those under maize / sweet potato intercropping or sweet potato sole cropping; this reduction in light interception was due to lower canopy development in sweet potato grown with soybean than with maize. Maize allowed a fairly good amount of sunrays to filter through the maize canopy to reach sweet potato canopy underneath. But the interception percentages under these three croppings did not differ significantly at the first and third dates of planting of sweet potato.

4.2.2.2 Experiment number 2b (1979 - 80)

The trend of variations in percentage light interception by sweet potato crop, under different intercropping systems during 1979 - 80 (Table 4.27), was similar to those described earlier in Experiment number 2a. High percentages of light interception by sweet potato cv. H-268, were recorded at 172 DAS under maize / sweet

Table 4.27 Percent light interception by sweet potato : Experiment number 2b (1979 - 80)

Treatment	55 DAS	87 DAS	172 DAS	238 DAS
Sweet potato planted at 0 DAS				
Sole SP_1	72.1	90.8	94.6	90.9
Soybean / SP_1	71.5	64.1	96.5	93.8
Maize / SP_1	43.3	74.7	99.4	98.7
Pigeonpea / SP_1	67.4	26.6	0.2	2.0
Sweet potato planted at 45 DAS				
Sole SP_1	55.0	71.8	83.9	85.7
Soybean / SP_1	49.2	32.9	79.2	90.5
Maize / SP_1	20.8	41.5	86.4	92.9
Pigeonpea / SP_1	48.3	20.2	0.7	3.5
Sweet potato planted at 0 DAS				
Sole SP_2	69.7	91.0	90.3	89.5
Soybean / SP_2	63.5	46.5	93.0	91.0
Maize / SP_2	33.0	62.1	95.6	94.5
Pigeonpea / SP_2	56.8	16.4	0.2	4.4
Sweet potato planted at 45 DAS				
Sole SP_2	40.0	70.9	77.4	79.1
Soybean / SP_2	40.8	22.6	71.2	80.7
Maize / SP_2	21.1	47.2	74.3	87.3
Pigeonpea / SP_2	14.0	10.4	0.1	2.3
S. Em $\pm$	3.32	3.25	3.67	3.43
C. D. at 5 %	9.59	9.38	10.60	9.90

Table 4.27 (continued)

Treatment	55 DAS	87 DAS	172 DAS	238 DAS
Sweet potato variety				
SP_1 = cv. H-268	53.5	52.8	67.6	69.8
SP_2 = cv. Local	42.4	45.9	62.8	66.1
S. Em ±	1.17	1.15	1.30	1.21
C. D. at 5 %	3.38	3.32	3.75	3.49
Cropping with sweet potato				
Sole sweet potato	59.2	81.1	86.6	86.3
Soybean / sweet potato	56.3	41.5	85.0	89.0
Maize / sweet potato	29.6	56.4	88.9	93.4
Pigeonpea / sweet potato	46.6	18.4	0.3	3.1
S. Em ±	1.66	1.62	1.83	1.71
C. D. at 5 %	4.79	4.68	5.28	4.94
Timing of planting of sweet potato				
0 DAS	59.7	59.0	71.2	70.6
45 DAS	36.2	39.7	59.2	65.3
S. Em ±	1.17	1.15	1.30	1.21
C. D. at 5 %	3.38	3.32	3.75	3.49

DAS = Days after sowing of grain crops

potato (99 %) and soybean / sweet potato (97 %) intercroppings and under sole cropping (95 %), when the component crops were established simultaneously. Between the two varieties of sweet potato, cv. H-268 intercepted more light (4 to 11 %) than the local variety throughout the growing period (Table 4.27).

Different croppings with sweet potato and their timings of planting had significant interaction effect on light interception by sweet potato at 87 and 172 days after sowing of grain crops (Table 4.28). The canopy developement of sweet potato when planted

Table 4.28 Interaction effect of different croppings with sweet potato and their timings of planting on percent light interception by sweet potato : Experiment number 2b (1979 - 80)

Cropping	At 87 DAS Timing of planting		At 172 DAS Timing of planting	
	0 DAS	45 DAS	0 DAS	45 DAS
Sole sweet potato	90.9	71.4	92.5	80.7
Soybean / sweet potato	55.3	27.8	94.8	75.2
Maize / sweet potato	68.4	44.4	97.5	80.4
Pigeonpea / sweet potato	21.5	15.3	0.2	0.4
S. Em ±	2.30		2.59	
C. D. at 5 %	6.64		7.48	

DAS = Days after sowing of grain crops

late was adversely affected. This resulted in better light interception by the early planted sweet potato, even when they were grown in association with maize or soybean. The canopy development of

sweet potato, when planted along with pigeonpea, was adversely affected and the light interception got reduced, so in pigeonpea / sweet potato intercropping, there was not much difference in light interception between the early and the late planted sweet potato crop.

4.2.2.3 Experiment number 2c (1980 - 81)

The percentage light intercepted by sweet potato during 1980 - 81 (Table 4.29) varied due to different cropping systems in the similar way, as has been described in the earlier experiments.

Two high-yielding varieties of sweet potato had no significant difference in respect of light interception up to 120 DAS (Table 4.29); afterwards sweet potato cv. Pusa Safed intercepted more solar radiation than cv. H-268.

A delay of 90 days in planting of sweet potato caused reduction in light interception as compared to those under simultaneous planting (Table 4.29), and thiswas due to the reduced canopy development of sweet potato. At the last date (240 DAS) of sampling, however, percentage light interception under delayed planting of sweet potato exceeded the value under simultaneous planting.

4.2.3 Yield

4.2.3.1 Experiment number 2a (1978 - 79)

Soybean : The grain yields of soybean, maize and pigeonpea and the tuber yield of sweet potato presented in Table 4.30 revealed

Table 4.29 Percent light interception by sweet potato : Experiment number 2c (1980 - 81)

Treatment	76 DAS	97 DAS	120 DAS	148 DAS	212 DAS	240 DAS
SP planted at 0 DAS						
Sole SP_1	81.3	84.3	86.4	88.9	88.6	79.2
Soybean / SP_1	62.5	65.0	84.5	91.0	93.5	84.8
Maize / SP_1	53.6	81.6	86.5	94.8	98.4	90.1
Pigeonpea / SP_1	52.3	16.5	12.0	9.3	7.3	15.0
SP planted at 90 DAS						
Sole SP_1				46.3	83.1	86.2
Soybean / SP_1				43.2	82.0	84.1
Maize / SP_1				56.7	92.6	94.0
Pigeonpea / SP_1				3.0	2.0	20.2
SP planted at 0 DAS						
Sole SP_2	85.9	87.0	88.7	92.0	93.0	83.1
Soybean / SP_2	65.7	67.0	84.9	92.8	96.1	88.5
Maize / SP_2	60.0	85.8	90.7	94.5	99.7	93.0
Pigeonpea / SP_2	50.3	20.0	15.2	13.0	9.9	19.5
SP planted at 90 DAS						
Sole SP_2				57.3	91.9	93.0
Soybean / SP_2				60.7	95.5	96.3
Maize / SP_2				66.7	97.5	99.8
Pigeonpea / SP_2				5.0	4.5	31.5
S. Em ±	3.11	2.66	2.30	2.56	3.42	3.49
C. D. at 5 %	9.15	7.82	6.76	7.39	9.87	10.08

Table 4.29 (continued)

Treatment	76 DAS	97 DAS	120 DAS	148 DAS	212 DAS	240 DAS
Sweet potato variety						
SP_1 = cv. H-268	62.4	61.9	67.4	54.2	68.1	69.2
SP_2 = cv. Pusa Safed	65.5	65.0	69.9	60.3	73.5	75.6
S. Em ±	1.56	1.33	1.15	0.91	1.21	1.23
C. D. at 5 %	NS	NS	NS	2.63	3.49	3.55
Cropping with sweet potato						
Sole SP	83.6	85.7	87.6	71.1	89.2	85.4
Soybean / SP	64.1	66.0	84.7	71.9	91.8	88.4
Maize / SP	56.8	83.7	88.6	78.2	96.3	94.2
Pigeonpea / SP	51.3	18.3	13.6	7.6	5.9	21.6
S. Em ±	2.20	1.88	1.63	1.28	1.71	1.75
C. D. at 5 %	6.47	5.53	4.79	3.70	4.94	5.05
Timing of planting of sweet potato						
0 DAS				72.0	72.9	69.2
90 DAS				42.4	68.6	75.6
S. Em ±				0.91	1.21	1.23
C. D. at 5 %				2.63	3.49	3.55

DAS = Days after sowing of grain crops, NS = Not significant,
SP = Sweet potato

that the highest yield of soybean (2808 kg / ha) was obtained from sole crop. The yield was reduced by 39 to 49 % when grown in association with sweet potato. The yield reduction decreased with the delay in planting of sweet potato. But the differences in soybean yield, under intercropping with sweet potato planted at different dates, were not significant.

Maize : The grain yield of maize (Table 4.30) was reduced by 21 % due to intercropping with sweet potato under simultaneous planting, as compared to sole crop yield of maize (4188 kg / ha). Sweet potato crop, planted at 45 or 90 days after maize sowing, offered no competition. Thus the maize yields with relay planted sweet potato were statistically at par with the sole crop yield.

Pigeonpea : The grain yield of pigeonpea (Table 4.30) decreased by 49 and 29 %, respectively, due to intercropping with sweet potato planted simultaneously and at 45 days after sowing of pigeonpea, as compared to the sole crop yield of pigeonpea (1050 kg / ha). When sweet potato was planted at 90 days after sowing of pigeonpea, the grain yield of pigeonpea was at par with sole crop yield.

Sweet potato : The tuber yield of sweet potato, presented in Table 4.30, indicated that under simultaneous planting tuber production increased by 8 and 24 %, respectively, due to intercropping with soybean and maize over the yield of sole crop (227 q / ha). The increase in tuber yield with soybean was, however, not significant. The tuber production, on the other hand, was reduced by 61 % when intercropped with pigeonpea.

Table 4.30 Grain yield of soybean, maize and pigeonpea (kg / ha) and tuber yield of sweet potato (q / ha) : Experiment number 2a (1978 - 79)

Treatment	Soy-bean	Maize	Pigeon-pea	Sweet potato
Sole soybean	2808			
Sole maize		4188		
Sole pigeonpea			1050	
Sweet potato planted at 0 DAS				
Sole sweet potato				227.1
Soybean / sweet potato	1417			244.2
Maize / sweet potato		3283		280.8
Pigeonpea / sweet potato			533	88.8
Sweet potato planted at 45 DAS				
Sole sweet potato				207.5
Soybean / sweet potato	1658			160.0
Maize / sweet potato		3950		237.9
Pigeonpea / sweet potato			747	66.3
Sweet potato planted at 90 DAS				
Sole sweet potato				132.1
Soybean / sweet potato	1713			117.9
Maize / sweet potato		4250		170.8
Pigeonpea / sweet potato			1121	35.4
S. Em ±	101.7	166.7	36.7	13.97
C. D. at 5 %	325.0	533.3	116.7	40.22
Cropping with sweet potato				
Sole sweet potato				188.9
Soybean / sweet potato				174.0
Maize / sweet potato				229.9
Pigeonpea / sweet potato				63.5
S. Em ±				8.07
C. D. at 5 %				23.22
Timing of planting of sweet potato				
0 DAS				210.2
45 DAS				167.9
90 DAS				114.1
S. Em ±				6.98
C. D. at 5 %				20.10
C. V.	10.7	8.5	8.6	17.0

DAS = Days after sowing of grain crops

When sweet potato was relay planted with soybean and maize, the tuber yields were similar to the sole crops planted on respective dates. However, the relay planted sweet potato crop produced more of tubers when it was grown with maize than with soybean; or in other words maize competed with sweet potato less adversely than soybean. The adverse effect of pigeonpea on relay planted sweet potato was very severe and the reductions in tuber yield as against the respective sole crops, were 68 and 73 % when sweet potato was planted at 45 and 90 days after sowing of pigeonpea, respectively.

The mean tuber yields under different croppings indicated that the increase in tuber production (22 %) under maize / sweet potato intercropping was appreciable. On the other hand, pigeonpea / sweet potato intercropping reduced the tuber production severely (66 %) as compared to the sole crop yield. The tuber production decreased significantly with the successive delay in planting. The reductions were 20 and 46 %, respectively, at the second and third dates of planting of sweet potato, over the yield obtained under simultaneous planting.

4.2.3.2 Experiment number 2b (1979 - 80)

Soybean : As compared to the sole crop yield (2963 kg / ha), the grain yield of soybean was reduced by 38 to 68 % due to competition with sweet potato (Table 4.31). The reduction in yield was more when local variety of sweet potato was intercropped and two crops were planted simultaneously (68 %). The adverse effect of competition was less severe (38 %) when soybean competed with the high-yielding variety (H-268) of sweet potato, planted at 45 days

Table 4.31 Grain yield of soybean, maize and pigeonpea (kg / ha) and tuber yield of sweet potato (q / ha) : Experiment number 2b (1979 - 80)

Treatment	Soy-bean	Maize	Pigeon-pea	Sweet potato
Sole soybean	2963			
Sole maize		4729		
Sole pigeonpea			1261	
Sweet potato planted at 0 DAS				
Sole SP_1				328.1
Soybean / SP_1	1354			358.1
Maize / SP_1		3008		410.0
Pigeonpea / SP_1			1058	76.9
Sweet potato planted at 45 DAS				
Sole SP_1				264.4
Soybean / SP_1	1833			245.2
Maize / SP_1		4315		294.2
Pigeonpea / SP_1			1350	14.4
Sweet potato planted at 0 DAS				
Sole SP_2				174.6
Soybean / SP_2	958			227.5
Maize / SP_2		2361		240.0
Pigeonpea / SP_2			792	22.9
Sweet potato planted at 45 DAS				
Sole SP_2				97.9
Soybean / SP_2	1313			95.6
Maize / SP_2		3957		133.3
Pigeonpea / SP_2			1157	5.6
S. Em ±	109.2	131.7	59.2	16.12
C. D. at 5 %	336.7	405.8	182.5	45.94

Table 4.31 (continued)

Treatment	Soy-bean	Maize	Pigeon -pea	Sweet potato
Sweet potato variety				
SP_1 = cv. H-268	1594	3662	1204	248.9
SP_2 = cv. Local	1136	3158	974	124.7
S. Em ±	77.5	93.3	41.7	5.70
C. D. at 5 %	239.2	287.5	128.3	16.25
Cropping with sweet potato				
Sole sweet potato				216.3
Soybean / sweet potato				231.6
Maize / sweet potato				269.4
Pigeonpea / sweet potato				30.0
S. Em ±				8.06
C. D. at 5 %				22.97
Timing of planting of sweet potato				
0 DAS	1157	2684	925	229.8
45 DAS	1573	4136	1253	143.8
S. Em ±	77.5	93.3	41.7	5.70
C. D. at 5 %	239.2	287.5	128.3	16.25
C. V.	13.0	7.2	10.5	17.3

DAS = Days after sowing of grain crops

later than soybean. The local variety of sweet potato had a viny growth habit and tended to climb over the adjacent rows of the component soybean crop. Soybean crop was more adversely affected by the local variety of sweet potato than with cv. H-268. The reduction in grain yield was 29 % more, when soybean was grown with local variety, than with high-yielding variety (H-268) of sweet potato. A delay of 45 days in planting of sweet potato increased the intercrop yield of soybean by 36 %.

Maize : The grain yield of maize was also reduced when grown in association with sweet potato (Table 4.31). The minimum competition (only 8 % reduction) was offered to maize crop, when it competed with sweet potato, cv. H-268, planted at 45 days after sowing of maize. Maximum maize grain yield reduction (50 %) was obtained when it was grown with the local variety of sweet potato under simultaneous planting.

The main effect of the variety of sweet potato on the maize grain yield was significant (Table 4.31). The maize crop was affected more when it grew with local variety (14 % reduction) than with cv. H-268. A delay of 45 days in planting of sweet potato caused 54 % increase in intercrop yield of maize over the yield (2684 kg / ha) obtained from simultaneous planting.

Pigeonpea : Pigeonpea was less affected due to intercropping with sweet potato (Table 4.31). Maximum reduction (37 %) in grain yield of pigeonpea was recorded when it was grown in combination with local variety of sweet potato, planted simultaneously, as compared to the sole crop yield (1261 kg / ha) of

pigeonpea. When pigeonpea was grown with relay planted sweet potato, the yields of pigeonpea were at par with the sole crop yield.

Local variety of sweet potato caused 19 % reduction in pigeonpea yield as compared to the yield recorded with cv. H-268. Pigeonpea yield was more (36 %) under relay planted sweet potato than under simultaneous planting.

Sweet potato : The trend of variations in tuber production under different intercropping systems (Table 4.31) was similar to that observed in Experiment number 1a (1978 - 79). Under simultaneous planting, the soybean / sweet potato intercropping produced 9 and 30 % higher tuber yield, respectively, with cv. H-268 and local variety of sweet potato, than under sole cropping of sweet potato. The increase in tuber production was 24 and 38 %, respectively, with cv. H-268 and local variety under maize / sweet potato intercropping, as compared to the respective sole crop yields.

Local variety produced 50 % lesser tuber yield than cv. H-268. A delay of 45 days in planting of sweet potato reduced the tuber yield by 37 % (Table 4.31). Under soybean / sweet potato intercropping tuber production was at par with the yields of sole crop of sweet potato. Under maize / sweet potato intercropping, tuber production was significantly more than those recorded under other intercroppings or sole croppings. Tuber production was drastically reduced (86 %) when sweet potato was intercropped with pigeonpea.

Two varieties of sweet potato interacted differently under different croppings and the interaction was statistically significant (Table 4.32). Although cv. H-268 yielded more than the local variety in most of the cases, yet in pigeonpea / sweet potato intercropping cv. H-268 failed to yield higher than the local variety.

Table 4.32 Interaction effect of sweet potato varieties and their different croppings on tuber production (q / ha) : Experiment number 2b (1979 - 80)

Cropping	Variety	
	H-268	Local
Sole sweet potato	296.3	136.3
Soybean / sweet potato	301.7	161.6
Maize / sweet potato	352.1	186.7
Pigeonpea / sweet potato	45.6	14.3
S. Em ±	11.40	
C. D. at 5 %	32.50	

The interaction effect of different croppings with sweet potato and their timings of planting was significant (Table 4.33).

Table 4.33 Interaction effect of different croppings with sweet potato and their timings of planting on tuber production (q / ha) : Experiment number 2b (1979 - 80)

Cropping	Timing of planting	
	0 DAS	45 DAS
Sole sweet potato	251.4	181.2
Soybean / sweet potato	292.8	170.4
Maize / sweet pogato	325.0	213.8
Pigeonpea / sweet potato	50.0	10.0
S. Em ±	11.40	
C. D. at 5 %	32.50	

Under soybean / sweet potato intercropping, tuber production was more than under sole cropping, when both crops were planted simultaneously; but when sweet potato was planted at 45 days after sowing of soybean, the yields were at par. Tuber production in maize / sweet potato intercropping as compared to in sole cropping was much higher under simultaneous planting than under relay planting.

4.2.3.3 Experiment number 2c (1980 - 81)

Soybean : The trend of variations in soybean grain yield under different cropping situations (Table 4.34), was very similar to those observed in the earlier experiments. Due to competition withe sweet potato, soybean yield was reduced by 63 to 65 % and 42 to 46 % , respectively,under simultaneous and relay planting of sweet potato, as compared to the yields (2577 kg / ha) recorded under sole cropping. Two varieties of sweet potato did not differ significantly in affecting the production of soybean grain yield, when grown in association with soybean. A delay of 90 days in planting of sweet potato offered minimum competition to soybean, and the intercrop yield of soybean was 54 % more than that was obtained under simultaneous planting.

Maize : The maize grain yield, when planted simultaneously with sweet potato, was significantly reduced (11 % with cv. H-268, 26 % with cv. Pusa Safed) as compared to the yields recorded under sole cropping. The maize grain yields with relay planted sweet potato were at par with the yields obtained under sole cropping (Table 4.34).

Table 4.34 Grain yield of soybean, maize and pigeonpea (kg / ha) and tuber yield of sweet potato (q/ ha) : Experiment number 2c (1980 - 81)

Treatment	Soy-bean	Maize	Pigeon-pea	Sweet potato
Sole soybean	2577			
Sole maize		4248		
Sole pigeonpea			1423	
Sweet potato planted at 0 DAS				
Sole SP_1				329.0
Soybean / SP_1	948			356.0
Maize / SP_1		3765		398.1
Pigeonpea / SP_1			1079	103.5
Sweet potato planted at 90 DAS				
Sole SP_1				169.6
Soybean / SP_1	1479			158.1
Maize / SP_1		4683		224.2
Pigeonpea / SP_1			1644	5.8
Sweet potato planted at 0 DAS				
Sole SP_2				421.0
Soybean / SP_2	907			447.9
Maize / SP_2		3132		464.8
Pigeonpea / SP_2			1012	131.3
Sweet potato planted at 90 DAS				
Sole SP_2				209.4
Soybean / SP_2	1379			201.7
Maize / SP_2		4396		273.5
Pigeonpea / SP_2			1536	14.0
S. Em ±	114.2	155.0	49.2	24.18
C. D. at 5 %	351.7	477.5	151.7	68.94

Table 4.34 (continued)

Treatment	Soy-bean	Maize	Pigeon-pea	Sweet potato
Sweet potato variety				
SP_1 = cv. H-268	1213	4224	1362	218.1
SP_2 = cv. Pusa Safed	1143	3763	1274	270.4
S. Em ±	80.8	110.0	35.0	8.55
C. D. at 5 %	NS	339.2	NS	24.37
Cropping with sweet potato				
Sole sweet potato				282.2
Soybean / sweet potato				290.9
Maize / sweet potato				340.2
Pigeonpea / sweet potato				63.7
S. Em ±				12.09
C. D. at 5 %				34.47
Timing of planting of sweet potato				
0 DAS	928	3448	1046	331.5
90 DAS	1429	4540	1590	157.0
S. Em ±	80.8	110.0	35.0	8.55
C. D. at 5 %	249.2	339.2	107.5	24.37
C. V.	15.7	7.7	7.4	19.8

DAS = Days after sowing of grain crops, NS = Not significant

The reduction in grain yield was more, when intercropped with cv. Pusa Safed than with H-268 variety of sweet potato. A delay (90 days) in planting of sweet potato increased the maize yield appreciably over that under simultaneous planting (Table 4.34).

Pigeonpea : Under simultaneous planting the reduction in pigeonpea yield was 24 to 29 % (Table 4.34), whereas, when sweet potato was planted at 90 days after sowing of pigeonpea there was 8 to 16 % increase in pigeonpea yields. The pigeonpea yield, when intercropped with late planted cv. Pusa Safed, was not significantly superior to that under sole cropping.

Sweet potato : The trend of variation in tuber production, due to different cropping systems (Table 4.34), was similar to those observed in earlier experiments. The tuber productions increased by 21 % over the sole crop yield of cv. H-268 under simultaneous planting of maize and sweet potato; but this difference in yield was not apparent when cv. Pusa Safed was used. Tuber yields were at par with sole cropping when both the varieties were planted simultaneously with soybean. Sweet potato tuber yields were reduced appreciably when it was intercropped with pigeonpea, more under relay planted condition. On an average, cv. Pusa Safed produced higher (24 %) tuber yield than cv. H-268.

Different croppings with sweet potato and their timings of planting had significant interaction effect on tuber production (Table 4.35). Under maize / sweet potato intercropping, tuber production was significantly higher than under soybean / sweet potato

intercropping, when sweet potato was planted at 90 days after sowing of maize or soybean. But this difference was not apparent when both the crops were established simultaneously.

Table 4.35 Interaction effect of different croppings with sweet potato and their timings of planting on tuber production (q / ha) : Experiment number 2c (1980 - 81)

Cropping	Timing of planting	
	0 DAS	90 DAS
Sole sweet potato	375.0	189.5
Soybean / sweet potato	402.0	180.0
Maize / sweet potato	431.5	248.9
Pigeonpea / sweet potato	117.4	10.0
S. Em ±	17.10	
C. D. at 5 %	48.74	

DAS = Days after sowing of grain crops

4.2.4 Aggressivity

The mean values of Aggressivity in respect of sweet potato, in combination with soybean or maize or pigeonpea (A_{sp}) have been summarised in Table 4.36.

4.2.4.1 Experiment number 2a (1978 - 79)

During 1978 - 79 (Table 4.36) sweet potato was the most aggressive (A_{sp} = 1.14), when it was grown in association with soybean under simultaneous planting. Under the same situation of planting, it was also fairly aggressive (A_{sp} = 0.91) in combination with maize. Sweet potato crop grown in association with soybean

Table 4.36 Aggressivity of sweet potato (in combination with soybean or maize or pigeonpea) : Experiment number 2a, b and c

Treatment	1978-79	1979-80	1980-81
Sweet potato planted at 0 DAS			
Soybean / SP_1		1.27	1.43
Maize / SP_1		1.23	0.65
Pigeonpea / SP_1		-1.21	-0.89
Sweet potato planted at 45 DAS			
Soybean / SP_1		0.26	
Maize / SP_1		-0.03	
Pigeonpea / SP_1		-2.05	
Sweet potato planted at 90 DAS			
Soybean / SP_1			-0.19
Maize / SP_1			-0.84
Pigeonpea / SP_1			-2.28
Sweet potato planted at 0 DAS			
Soybean / SP_2	1.14	1.96	1.42
Maize / SP_2	0.91	1.75	0.73
Pigeonpea / SP_2	-0.23	-0.99	-0.80
Sweet potato planted at 45 DAS			
Soybean / SP_2	0.23	0.21	
Maize / SP_2	0.21	-0.15	
Pigeonpea / SP_2	-0.84	-1.77	
Sweet potato planted at 90 DAS			
Soybean / SP_2	-0.18		-0.11
Maize / SP_2	-0.53		-0.77
Pigeonpea / SP_2	-1.82		-2.09
Sweet potato variety			
SP_1 = cv. H-268		-0.09	-0.35
SP_2 = cv. Local/Pusa Safed		0.17	-0.27
Cropping with sweet potato			
Soybean / sweet potato	0.40	0.92	0.64
Maize / sweet potato	0.20	0.70	-0.06
Pigeonpea / sweet potato	-0.97	-1.51	-1.51
Timing of planting of sweet potato			
0 DAS	0.60	0.67	0.43
45 DAS	-0.13	-0.59	
90 DAS	-0.84		-1.05

DAS = Days after sowing of grain crops, SP_2 = cv. Local during 1978-79 and 1979-80 and cv. Pusa Safed during 1980-81

or maize, was observed less dominant (A_{sp} ranging from 0.21 to 0.23), when planting was delayed by 45 days. Under all other situations of intercropping, sweet potato was dominated by the component crops as indicated by negative values of Aggressivity. Pigeonpea was always dominant over sweet potato (A_{sp} ranging from -0.23 to -1.82) and the dominance increased with the delay in planting of sweet potato.

On an average, sweet potato was aggressive when it was intercropped with soybean and maize; the Aggressivity value was higher with soybean than with maize (Table 4.36). Sweet potato was observed to be dominant only under simultaneous planting situation (A_{sp} = 0.60). The dominance of the component crops over sweet potato increased with delay in planting of sweet potato.

4.2.4.2 Experiment number 2b (1979 - 80)

During 1979 - 80 the Aggressivity values of sweet potato (Table 4.36) were to some extent higher than those of Experiment number 2a (1978 - 79); but the trend of variation was more or less similar to that in the previous year. The mean Aggressivity value of sweet potato was slightly higher with the local variety than with the high yielding variety H-268.

4.2.4.3 Experiment number 2c (1980 - 81)

Aggressivity values of sweet potato, in combination with soybean or maize or pigeonpea during 1980 - 81 under different planting situations (Table 4.36) varied in the way similar to that was observed in the earlier experiments.

On an average, both the varieties of sweet potato were dominated by other grain crops, the values being negative(A_{sp} =-0.27 to -0.35). In the previous year (1979 - 80) the local variety appeared to be slightly more aggressive over the other grain crops (A_{sp} = 0.17) as compared to cv. H-268 (A_{sp} = -0.09).

4.2.5 Land Equivalent Ratio

The Land Equivalent Ratio (LER) values of each variety of sweet potato were calculated on the basis of respective sole crop yield of sweet potato, planted at the time of sowing of grain crops.

4.2.5.1 Experiment number 2a (1978 - 79)

Under intercropping situations the LER values of soybean increased gradually with delay in planting of sweet potato (Table 4.37). Similar trend of variation was also recorded in respect of the LER values of maize and pigeonpea.

The LER value of sweet potato (Table 4.37), under simultaneously planted maize / sweet potato intercropping, was highest (1.24) and was significantly higher than those under other sole and intercroppings. The LER values of sweet potato,under soybean / sweet potato intercropping, where both the crops were established simultaneously (1.08) and under maize / sweet potato intercropping, where sweet potato was planted at 45 days after sowing of maize (1.05), were comparable with that of sole cropping of sweet potato planted at the time of sowing of grain crops. The LER values of sweet potato was appreciably reduced when grown in association with pigeonpea; the values decreased with the delay in planting of sweet potato.

Table 4.37 Land Equivalent Ratio for soybean, maize, pigeonpea, sweet potato and combined yields : Experiment number 2a (1978 - 79)

Treatment	Soy-bean	Maize	Pigeon-pea	Sweet potato	Comb-ined
Sole soybean	1.00				1.00
Sole maize		1.00			1.00
Sole pigeonpea			1.00		1.00
Sweet potato planted at 0 DAS					
Sole sweet potato				1.00	1.00
Soybean/sweet potato	0.51			1.08	1.59
Maize/sweet potato		0.79		1.24	2.03
Pigeonpea/sweet potato			0.51	0.39	0.90
Sweet potato planted at 45 DAS					
Sole sweet potato				0.92	0.92
Soybean/sweet potato	0.59			0.71	1.30
Maize/sweet potato		0.95		1.05	2.00
Pigeonpea/sweet potato			0.71	0.29	1.00
Sweet potato planted at 90 DAS					
Sole sweet potato				0.58	0.58
Soybean/sweet potato	0.61			0.52	1.13
Maize/sweet potato		1.02		0.75	1.77
Pigeonpea/sweet potato			1.07	0.16	1.23
S. Em ±	0.036	0.040	0.035	0.062	0.054
C. D. at 5 %	0.116	0.127	0.111	0.177	0.154
C. x T.P.				NS	**
Cropping with sweet potato (C.)					
Sole sweet potato				0.83	0.83
Soybean/sweet potato				0.77	1.34
Maize/sweet potato				1.01	1.93
Pigeonpea/sweet potato				0.28	1.04
S. Em ±				0.036	0.031
C. D. at 5 %				0.102	0.089
Timing of planting of sweet potato (T.P.)					
0 DAS				0.93	1.38
45 DAS				0.74	1.30
90 DAS				0.50	1.18
S. Em ±				0.031	0.027
C. D. at 5 %				0.089	0.077

DAS = Days after sowing of grain crops, NS = Not significant,
** = Significant at 1 %

Among the three intercroppings with sweet potato, maize / sweet potato recorded maximum LER value of sweet potato (1.01). Pigeonpea / sweet potato intercropping, on the other hand, contributed the minimum LER value of sweet potato (0.28). The LER values of sweet potato decreased with the delay in its planting (Table 4.37).

It is interesting to note that the LER values for the combined intercrop yields (Table 4.37) recorded 103 and 100 % yield advantage in maize / sweet potato intercropping, respectively, when sweet potato was planted along with maize and at 45 days after maize sowing. The other intercropping systems, which were found to be advantageous over sole cropping, were (i) soybean / sweet potato intercropping, established simultaneously (1.59) or sweet potato planted at 45 days after sowing of soybean (1.30), (ii) maize / sweet potato (1.77) and pigeonpea / sweet potato (1.23) intercroppings, when sweet potato was planted at 90 days after sowing of grain crops.

On an average, the effects of different croppings were significant on the total LER values (Table 4.37). All the three intercroppings were observed to be advantageous over sole cropping. Greatest advantage of intercropping was recorded with maize / sweet potato (1.93), followed by soybean / sweet potato (1.34) and pigeonpea / sweet potato intercroppings (1.04). The total LER values were found to decrease with the delay in planting of sweet potato.

The interaction effect of different croppings with sweet potato and their timings of planting was significant on the LER values for the combined yields (Table 4.37). The LER value for total yields under pigeonpea / sweet potato intercropping was at par

with sole croppings, when sweet potato was planted simultaneously and at 45 days after sowing of grain crops, but this intercropping became superior to sole cropping when sweet potato was planted at 90 days after sowing of pigeonpea. Pigeonpea / sweet potato intercropping was found to be inferior to other intercroppings under the first and second dates, but under the third date of planting of sweet potato it was equal to intercropping of soybean / sweet potato.

4.2.5.2 Experiment number 2b (1979 - 80)

The Land Equivalent Ratio (LER) values of soybean, maize and sweet potato and the combined yields of component crops during 1979 - 80 (Table 4.38) varied in the way similar to that, as recorded in Experiment number 2a. This year, two varieties of sweet potato were tried. The LER values of soybean, maize and pigeonpea were comparatively higher, while they grew in association with cv. H-268 than in association with the local variety of sweet potato. The average LER values of the two varieties of sweet potato did not differ significantly. The LER values for the combined yields were higher, when the grain crops were grown with cv. H-268 (1.33) than with the local variety (1.17) of sweet potato.

4.2.5.3 Experiment number 2c (1980 - 81)

The LER values of soybean, maize, pigeonpea, sweet potato and combined intercrop yields (Table 4.39) followed similar trend of variation as discussed in the earlier experiments. Another high yielding variety of sweet potato, Pusa Safed, replaced the local variety, and the LER values of maize with cv. Pusa Safed

Table 4.38 Land Equivalent Ratio for soybean, maize, pigeonpea, sweet potato and combined yields : Experiment number 2b (1979 - 80)

Treatment	Soy-bean	Maize	Pigeon-pea	Sweet potato	Comb-ined
Sole soybean	1.00				1.00
Sole maize		1.00			1.00
Sole pigeonpea			1.00		1.00
Sweet potato planted at 0 DAS					
Sole SP_1				1.00	1.00
Soybean / SP_1	0.46			1.09	1.55
Maize / SP_1		0.64		1.25	1.89
Pigeonpea / SP_1			0.84	0.24	1.08
Sweet potato planted at 45 DAS					
Sole SP_1				0.80	0.80
Soybean / SP_1	0.62			0.75	1.37
Maize / SP_1		0.92		0.90	1.82
Pigeonpea / SP_1			1.07	0.05	1.12
Sweet potato planted at 0 DAS					
Sole SP_2				(0.53)1.00	1.00
Soybean / SP_2	0.32			1.30	1.62
Maize / SP_2		0.50		1.38	1.88
Pigeonpea / SP_2			0.63	0.13	0.76
Sweet potato planted at 45 DAS					
Sole SP_2				0.56	0.56
Soybean / SP_2	0.44			0.55	0.99
Maize / SP_2		0.84		0.77	1.61
Pigeonpea / SP_2			0.92	0.03	0.95
S. Em ±	0.037	0.028	0.047	0.139	0.074
C. D. at 5 %	0.114	0.086	0.145	0.396	0.210

Table 4.38 (continued)

Treatment	Soy-bean	Maize	Pigeon-pea	Sweet potato	Comb-ined
Sweet potato variety					
SP_1 = cv. H-268	0.54	0.78	0.96	0.76	1.33
SP_2 = cv. Local	0.38	0.67	0.77	0.72	1.17
S. Em ±	0.026	0.020	0.033	0.049	0.026
C. D. at 5 %	0.081	0.061	0.102	NS	0.074
Cropping with sweet potato					
Sole sweet potato				0.84	0.84
Soybean / sweet potato				0.92	1.38
Maize / sweet potato				1.07	1.79
Pigeonpea / sweet potato				0.11	0.97
S. Em ±				0.069	0.037
C. D. at 5 %				0.197	0.105
Timing of planting of sweet potato					
0 DAS	0.39	0.57	0.73	0.92	1.35
45 DAS	0.53	0.88	0.99	0.55	1.15
S. Em ±	0.026	0.020	0.033	0.049	0.026
C. D. at 5 %	0.081	0.061	0.102	0.140	0.074

DAS = Days after sowing of grain crops, NS = Not significant,
Figure in parenthesis is the LER of SP_2 as compared to SP_1

Table 4.39 Land Equivalent Ratio for soybean, maize, pigeonpea, sweet potato and combined yields : Experiment number 2c (1980 - 81)

Treatment	Soy-bean	Maize	Pigeon-pea	Sweet potato	Comb-ined
Sole soybean	1.00				1.00
Sole maize		1.00			1.00
Sole pigeonpea			1.00		1.00
Sweet potato planted at 0 DAS					
Sole SP_1				1.00	1.00
Soybean / SP_1	0.37			1.08	1.45
Maize / SP_1		0.89		1.21	2.10
Pigeonpea / SP_1			0.76	0.32	1.08
Sweet potato planted at 90 DAS					
Sole SP_1				0.52	0.52
Soybean / SP_1	0.58			0.48	1.06
Maize / SP_1		1.11		0.68	1.79
Pigeonpea / SP_1			1.16	0.02	1.18
Sweet potato planted at 0 DAS					
Sole SP_2				(1.28)1.00	1.00
Soybean / SP_2	0.35			1.07	1.42
Maize / SP_2		0.74		1.11	1.85
Pigeonpea / SP_2			0.71	0.31	1.02
Sweet potato planted at 90 DAS					
Sole SP_2				0.50	0.50
Soybean / SP_2	0.54			0.48	1.02
Maize / SP_2		1.04		0.65	1.69
Pigeonpea / SP_2			1.08	0.03	1.11
S. Em ±	0.044	0.037	0.035	0.058	0.063
C. D. at 5 %	0.136	0.112	0.107	0.165	0.179

Table 4.39 (continued)

Treatment	Soy-bean	Maize	Pigeon-pea	Sweet potato	Comb-ined
Sweet potato variety					
SP_1 = cv. H-268	0.47	1.00	0.96	0.66	1.27
SP_2 = cv. Pusa Safed	0.44	0.89	0.89	0.64	1.20
S. Em ±	0.031	0.026	0.025	0.021	0.022
C. D. at 5 %	NS	0.080	NS	NS	0.062
Cropping with sweet potato					
Sole sweet potato				0.75	0.75
Soybean / sweet potato				0.78	1.23
Maize / sweet potato				0.91	1.85
Pigeonpea / sweet potato				0.17	1.10
S. Em ±				0.029	0.032
C. D. at 5 %				0.083	0.091
Timing of planting of sweet potato					
0 DAS	0.36	0.81	0.74	0.89	1.36
90 DAS	0.56	1.07	1.12	0.42	1.11
S. Em ±	0.031	0.026	0.025	0.021	0.022
C. D. at 5 %	0.097	0.080	0.076	0.060	0.062

DAS = Days after sowing of grain crops, NS = Not significant,
Figure in parenthesis is the LER of SP_2 as compared to SP_1

in the present experiment, were not so low as was observed in Experiment number 2b with the local variety of sweet potato. The LER values of soybean, pigeonpea and sweet potato did not differ due to the differences in the growth habits of the two varieties of sweet potato during 1980 - 81. The LER values of maize differed due to the differences in the sweet potato varieties and higher value was obtained with cv. H-268 than with cv. Pusa Safed.

The interaction effect of different croppings with sweet potato and their timings of planting on LER values of sweet potato was significant. The results summarised in Table 4.40 indicated that the LER value of sweet potato in soybean / sweet potato intercropping was as good as in maize / sweet potato intercropping under simultaneous planting situation. When planting of sweet potato was delayed by 90 days, the LER value became significantly lower under soybean / sweet potato intercropping than in maize / sweet potato intercropping.

Table 4.40 Interaction effect of different croppings with sweet potato and their timings of planting on LER values of sweet potato : Experiment number 2c (1980 - 81)

Cropping	Timing of planting	
	0 DAS	90 DAS
Sole sweet potato	1.00	0.51
Soybean / sweet potato	1.07	0.48
Maize / sweet potato	1.16	0.67
Pigeonpea / sweet potato	0.31	0.03
S. Em ±	0.041	
C. D. at 5 %	0.117	

DAS = Days after sowing of grain crops

Maximum advantage of intercropping (110 %) was obtained when H-268 variety of sweet potato was intercropped with maize planted simultaneously (Table 4.39). The same intercropping system with cv. Pusa Safed recorded 85 % yield advantage over sole cropping. The increases in total LER values ranged from 42 to 45 %, under soybean / sweet potato intercropping over sole cropping, when both the crops were planted simultaneously. Pigeonpea / sweet potato intercropping failed to produce any advantage under any situation.

Variation in the total LER values (during 1980 - 81) due to different croppings and dates of planting of sweet potato followed similar trend as mentioned in the earlier experiments. The value was comparatively higher with cv. H-268 than with cv. Pusa Safed (Table 4.39).

The LER values for the combined intercrop yields differed significantly due to the interaction effect of different croppings with sweet potato and their timings of planting (Table 4.41).

Table 4.41 Interaction effect of different croppings with sweet potato and their timings of planting on total LER values : Experiment number 2c (1980 - 81)

Cropping	Timing of planting	
	0 DAS	90 DAS
Sole sweet potato	1.00	0.51
Soybean / sweet potato	1.43	1.04
Maize / sweet potato	1.97	1.74
Pigeonpea / sweet potato	1.05	1.14
S. Em ±	0.045	
C. D. at 5 %	0.128	

DAS = Days after sowing of grain crops

The pigeonpea / sweet potato intercropping did not show much advantage over sole cropping of sweet potato, when planted simultaneously. But this intercropping showed 63 % yield advantages over the respective sole crop of sweet potato when planting of sweet potato was delayed.

Summarising the LER values of Experiment number 2 (1978 - 79 to 1980 - 81), it is apparent that the LER values of soybean, maize and pigeonpea under different intercropping situations increased with the delay in planting of sweet potato. Under the situations of relay planting of sweet potato, particularly at 90 days after first planting, the values of maize and pigeonpea became equal to those of respective sole croppings. The LER value of sweet potato was maximum and even appreciably higher than that of sole cropping under maize / sweet potato intercropping, when the two crops were planted at a time. Under the situation of simultaneous planting, soybean / sweet potato (high-yielding varieties) intercroppting also showed LER values of sweet potato more than 1.00. The values were very low (less than 40 % of sole cropping) under pigeonpea / sweet potato intercropping. The LER values of sweet potato always decreased with the delay in its planting. Maize / sweet potato intercropping proved to be the most advantageous, particularly under simultaneous planting situations. Simultaneously established soybean / sweet potato intercropping also showed appreciable yield advantage. Under relay planting situations also, the intercroppings produced fairly high yield advantages as compared to the respective sole croppings of sweet potato. Pigeonpea / sweet potato intercropping was less advantageous than other intercroppings.

4.2.6 Competitive Ratio

Competitive Ratio (CR) values of the two crops are the reciprocals of each other. So, the values of only one crop, i.e., sweet potato have been presented in Table 4.42 and are being discussed hereunder.

4.2.6.1 Experiment number 2a (1978 - 79)

The CR values of sweet potato were highest under soybean / sweet potato intercropping (CR_{sp} = 2.24), when both crop were planted at the same time (Table 4.42). The value was significantly higher than those under other intercroppings. The second highest value (1.59) was obtained in maize / sweet potato intercropping under simultaneous establishment. This value (1.59) was not significantly superior to those of the above two intercroppings when sweet potato was planted at 45 days after sowing of the grain crops. Under all other situations of intercropping, competitive ability of sweet potato was reduced, (CR_{sp} = less than 1.00) or in other words the other component crops became more competitive. Pigeonpea was always more competitive under pigeonpea / sweet potato intercroppings. Delay in planting of sweet potato caused lowering of CR values of sweet potato.

The CR values of sweet potato (1.45) in soybean / sweet potato intercropping was significantly higher than those in other two intercroppings (Table 4.42). Sweet potato was also more competitive (CR_{sp} = 1.15) than the component crop under maize / sweet potato intercropping. In pigeonpea / sweet potato intercropping, pigeonpea had much higher competitive ability over sweet potato

Table 4.42 Competitive Ratio of sweet potato (in combination with soybean or maize or pigeonpea) : Experiment number 2a, b and c

Treatment	1978-79	1979-80	1980-81
Sweet potato planted at 0 DAS			
Soybean / SP_1		2.40	3.12
Maize / SP_1		1.98	1.37
Pigeonpea / SP_1		0.28	0.44
Sweet potato planted at 45 DAS			
Soybean / SP_1		1.22	
Maize / SP_1		0.98	
Pigeonpea / SP_1		0.05	
Sweet potato planted at 90 DAS			
Soybean / SP_1			0.85
Maize / SP_1			0.62
Pigeonpea / SP_1			0.02
Sweet potato planted at 0 DAS			
Soybean / SP_2	2.24	4.13	3.20
Maize / SP_2	1.59	2.83	1.49
Pigeonpea / SP_2	0.79	0.21	0.44
Sweet potato planted at 45 DAS			
Soybean / SP_2	1.25	1.26	
Maize / SP_2	1.11	0.93	
Pigeonpea / SP_2	0.42	0.04	
Sweet potato planted at 90 DAS			
Soybean / SP_2	0.87		0.92
Maize / SP_2	0.74		0.63
Pigeonpea / SP_2	0.15		0.03
S. Em $\pm$	0.165	0.165	0.243
C. D. at 5 %	0.482	0.475	0.700

Table 4.42 (continued)

Treatment	1978-79	1979-80	1980-81
Sweet potato variety			
SP_1 = cv. H-268		1.15	1.07
SP_2 = cv. Local/Pusa Safed		1.57	1.12
S. Em ±		0.067	0.099
C. D. at 5 %		0.193	NS
Cropping with sweet potato			
Soybean / sweet potato	1.45	2.25	2.02
Maize / sweet potato	1.15	1.68	1.03
Pigeonpea / sweet potato	0.45	0.14	0.23
S. Em ±	0.095	0.083	0.121
C. D. at 5 %	0.277	0.239	0.348
Timing of planting of sweet potato			
0 DAS	1.54	1.97	1.68
45 DAS	0.93	0.75	
90 DAS	0.58		0.51
S. Em ±	0.095	0.067	0.099
C. D. at 5 %	0.277	0.193	0.285

DAS = Days after sowing of grain crops, NS = Not significant,
SP_2 = cv. Local during 1978-79 and 1979-80 and cv. Pusa Safed during 1980-81

(CR_{sp} = 0.45). Delay in planting reduced Competitive Ratio values of sweet potato and so the competitive ability of the component crops increased with delay in planting of sweet potato.

4.2.6.2 Experiment number 2b (1979 - 80)

Sweet potato was more competitive than soybean under both simultaneous and relay planting situations (Table 4.42). The degree of competitive ability was much higher under simultaneous planting situation (CR_{sp} = 2.40 for cv. H-268 and 4.13 for local variety) than where sweet potato was planted late. Sweet potato was also recorded to be more competitive than maize when they were established simultaneously, the CR values of sweet potato being higher (2.83) with local variety than with cv. H-268 (1.98). The competitive ability of pigeonpea was much higher than that of sweet potato, as the CR values of sweet potato varied from 0.04 to 0.28 under pigeonpea / sweet potato intercroppings. The values decreased with the delay in planting of sweet potato under all intercroppings. The variation in the CR values of sweet potato due to different croppings and dates of planting of sweet potato showed similar trend, as has been discussed previously.

Varieties of sweet potato and their different croppings had significant interaction effect on the CR values of sweet potato (Table 4.43). The CR values of sweet potato under soybean / sweet potato and maize / sweet potato intercroppings had no difference when H-268 variety of sweet potato was used whereas, the value was much higher with soybean as component crop than with maize, when local variety of sweet potato was used.

Table 4.43 Interaction effect of sweet potato varieties and their different croppings on CR values of sweet potato : Experiment number 2b (1979 - 80)

Cropping	Variety	
	H-268	Local
Soybean / sweet potato	1.81	2.69
Maize / sweet potato	1.48	1.88
Pigeonpea / sweet potato	0.16	0.12
S. Em ±	0.117	
C. D. at 5 %	0.337	

The interaction effect of varieties of sweet potato and their timings of planting was also significant on the CR values of sweet potato (Table 4.44). The degree of competitive ability of the local variety of sweet potato was found to be much higher than that of cv. H-268 under simultaneous planting situation,but when sweet potato was planted at 45 days after sowing of the grain crops, both the varieties had CR values less than 1.00 and were at par in this respect.

Table 4.44 Interaction effect of sweet potato varieties and their timings of planting on CR values of sweet potato : Experiment number 2b (1979 - 80)

Timing of planting	Variety	
	H-268	Local
0 DAS	1.56	2.39
45 DAS	0.75	0.74
S. Em ±	0.095	
C. D. at 5 %	0.273	

DAS = Days after sowing of grain crops

The CR values of sweet potato differed significantly due to the interaction effect of different croppings and timings of planting of sweet potato (Table 4.45). When sweet potato was planted along with component crops, competitive ratio values were higher in soybean / sweet potato intercropping than under maize / sweet potato intercropping. But when the planting of sweet potato was delayed by 45 days, there was appreciable reduction in CR values and the differences between the intercroppings of sweet potato with maize and soybean were not significant.

Table 4.45 Interaction effect of different croppings with sweet potato and their timings of planting on CR values of sweet potato : Experiment number 2b (1979 - 80)

Cropping	Timing of planting	
	0 DAS	45 DAS
Soybean / sweet potato	3.26	1.24
Maize / sweet potato	2.41	0.95
Pigeonpea / sweet potato	0.25	0.04
S. Em ±	0.117	
C. D. at 5 %	0.337	

DAS = Days after sowing of grain crops

4.2.6.3 Experiment number 2c (1980 - 81)

The CR values of sweet potato during 1980 - 81 (Table 4.42) varied in the way, similar to those recorded in the earlier experiments. Local variety of sweet potato was replaced by a high-yielding cv. Pusa Safed. The CR values of cv. H-268 and Pusa Safed did not differ significantly.

The interaction effect of different croppings with sweet potato and their timings of planting on the CR values of sweet potato was significant (Table 4.46). The competitive ability of sweet potato was much higher, when intercropped with soybean (CR_{sp} = 3.16) than with maize (CR_{sp} = 1.43) under the situation of simultaneous planting. When sweet potato was planted at 90 days after sowing of grain crops, sweet potato appeared to be no more competitive (CR_{sp} less than 1.00) over the component crops and the CR values of sweet potato with soybean and maize did not differ significantly.

Table 4.46 Interaction effect of different croppings with sweet potato and their timings of planting on CR values of sweet potato : Experiment number 2c (1980 - 81)

Cropping	Timing of planting	
	0 DAS	90 DAS
Soybean / sweet potato	3.16	0.88
Maize / sweet potato	1.43	0.62
Pigeonpea / sweet potato	0.44	0.03
S. Em ±	0.172	
C. D. at 5 %	0.495	

DAS = Days after sowing of grain crops

Thus, it was observed that the CR values of sweet potato were maximum with soybean, followed by maize, as component crop, under simultaneous establishment. Pigeonpea was much more competitive than sweet potato. Delay in planting of sweet potato reduced the tuber yield, favoured the grain crops and ultimately reduced the CR values of sweet potato.

5. DISCUSSION

Sweet potato is an important food crop of multifarious uses. The roots as well as the vines are used both as human as well as cattle feed. Its yield potential is very high. It is drought tolerant and can grow very well in alluvial soil, with the productivity depending upon inherent soil fertility and fertilizer applied to the crop. One of the drawbacks of this crop is that it is of longer duration than that of many other high-yielding cereal and grain legume crops. In the present work,an effort has been made to analyse the growth and yield of the component crops, when it is grown in association with other cereal and grain legume crops as compared to their growth as sole crops. In one series of the experiments, soybean was intercropped with sweet potato under different spatial arrangements and relayed plantings of sweet potato. In another series of the experiments, the productivity was analysed when two tall (maize and pigeonpea) and one semi-dwarf (soybean) crops were intercropped with sweet potato.

Sweet potato is usually planted in the mid or late rainy season (from July onwards). When planted in mid-July, it took about 150 days to attain its maximum leaf weight (Fig. 5.1, 5.2) and the crop started initiating root tubers at about 110 days after planting. The main period of tuber bulking was from November to February and the crop was harvested during February. When planted by the end of August, the growth of stem was reduced, the maximum amount of leaf growth was attained at 150 days after planting and the tuber initiation took place nearly at the same time

of the earlier planted crop, i.e., about 80 days after planting. When the crop was planted in the middle of October, the growth of both the stem and leaf of sweet potato was reduced, and the initiation of tubers commenced late, i.e., about 90 days after planting and the bulking was low as compared to that of the earlier planted crops.

This provided adequate scope for the development of the companion crops like soybean cv. Bragg (which took 110 - 115 days to mature) and maize cv. Diara Composite (which took 95 days to mature). The other experimental crop, pigeonpea cv. AS-8 (harvested at 220 to 240 days after sowing) was of long duration, similar to that of sweet potato (200 days when planted in middle of July).

5.1 Dry matter accumulation in different crops and light interception by sweet potato under different cropping systems

The dry matter accumulations under different cropping systems have earlier been presented and partly discussed in the chapter on 'Results'. In the experiment on intercropping of soybean with sweet potato under different spatial arrangements, the main features, as depicted in Fig. 5.1, were as follows :

(i) The growth of leaf, stem and tuber of sweet potato, under the intercropping system of 1 : 1 alternate rows (60 cm apart) of soybean and sweet potato, was as good as that of the sole crop of sweet potato (60 cm x 30 cm), when planted in the middle of July. Both the crops intercepted, more or less, similar amount of light.

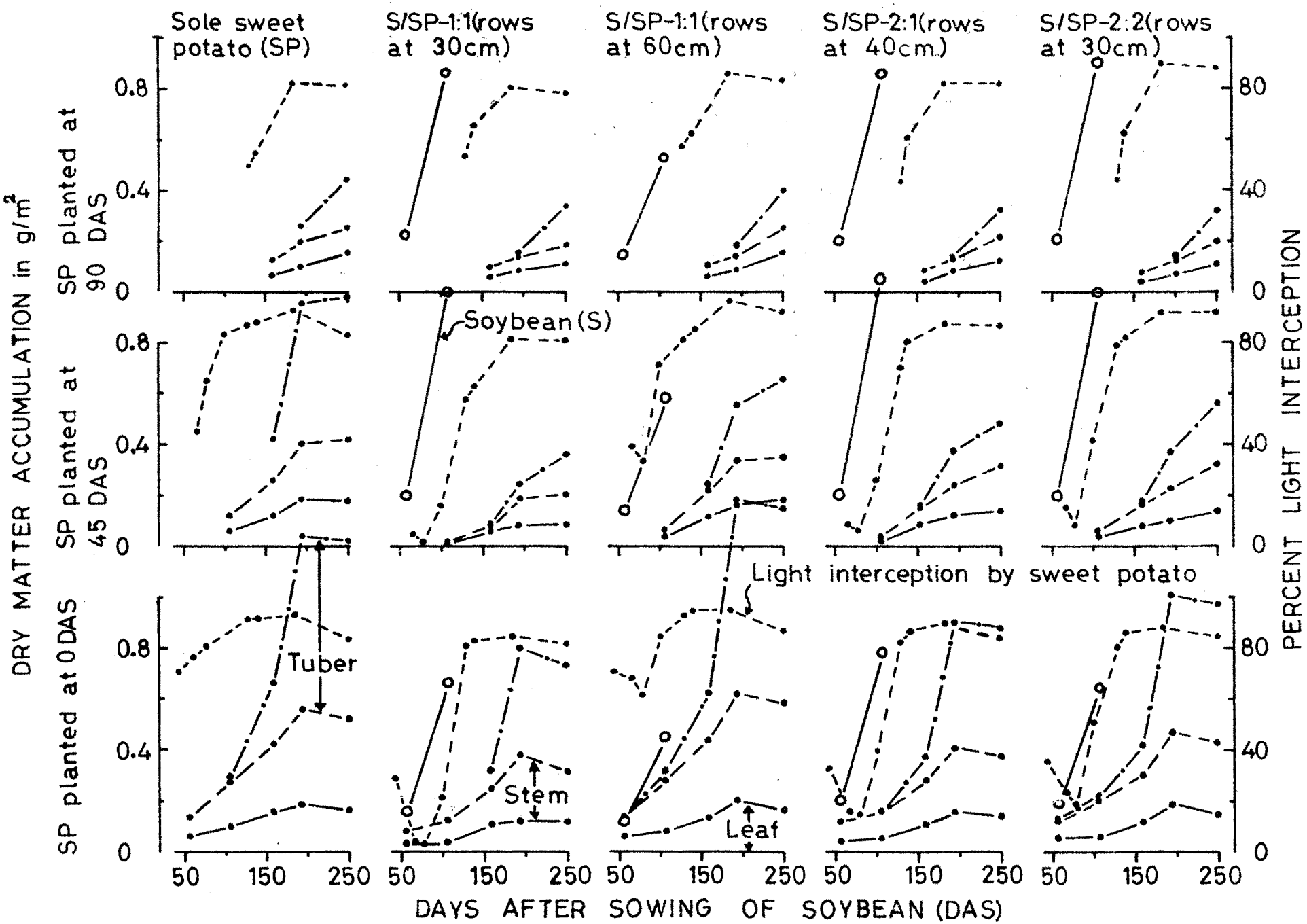

Fig. 5.1 DRY MATTER ACCUMULATION IN DIFFERENT PLANT PARTS OF SWEET POTATO AND SHOOT OF SOYBEAN AND LIGHT INTERCEPTION BY SWEET POTATO AT DIFFERENT TIMINGS UNDER VARIED CROPPING SYSTEMS : Expt. No. 1c (1979 - 80)

(ii) When sweet potato utilised the resources in between the two rows of soybean spaced at 120, 90, 80 and 60 cm (in 1 : 1, 2 : 2, 2 : 1 and 1 : 1 soybean / sweet potato rows at 60, 30, 40 and 30 cm apart, respectively), there were increasing levels of reduction in leaf, stem and tuber growth in sweet potato. When soybean and sweet potato were grown in alternate rows 30 cm apart, the light interception by sweet potato canopy was appreciably reduced.

(iii) Later plantings of sweet potato in the established stand of soybean reduced the growth of sweet potato. Under the intercropping of soybean with relay planted sweet potato at 1 : 1 alternate rows (60 cm apart), sweet potato recorded lesser growth than under the sole crop to the contrary of the cropping system, when both were established simultaneously.

In the experiment on the intercropping of soybean, maize and pigeonpea with sweet potato (Fig. 5.2), the salient features were as follows :

(i) Under the intercropping system of maize with sweet potato, the growth of the leaf, stem and tuber of sweet potato was slightly better than that recorded under sole cropping systems. The pigeonpea, which matured late, reduced drastically the growth of sweet potato. The light interception by the sole crop of sweet potato was very similar to that intercepted by sweet potato under the maize / sweet potato and soybean / sweet potato intercropping systems, particularly at the later stages of growth of sweet potato.

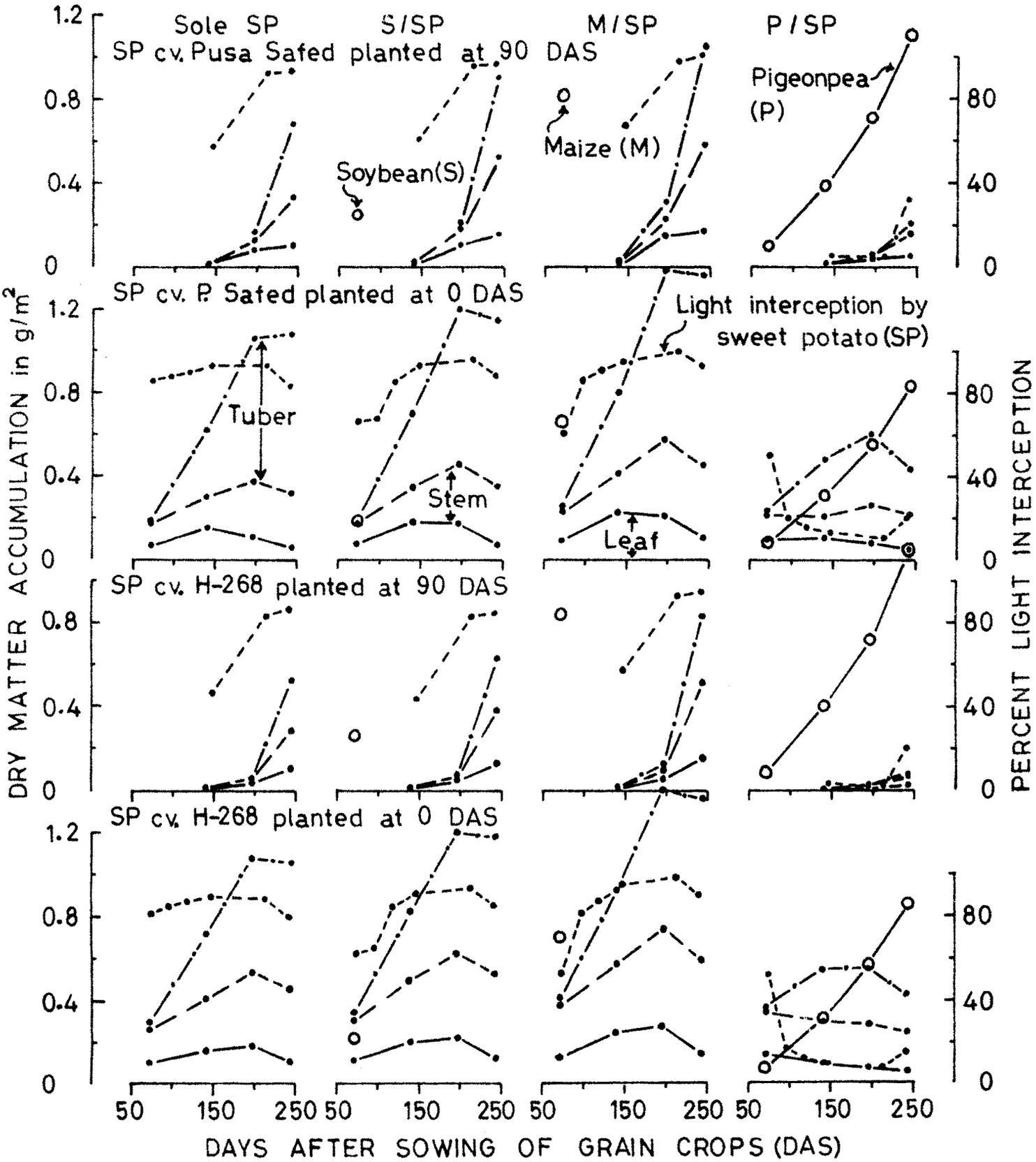

Fig. 5.2 DRY MATTER ACCUMULATION IN DIFFERENT PLANT PARTS OF SWEET POTATO AND SHOOT OF GRAIN CROPS AND LIGHT INTERCEPTION BY SWEET POTATO AT DIFFERENT TIMINGS UNDER VARIED CROPPING SYSTEMS : Expt. No. 2c (1980-81)

(ii) Late planting of sweet potato reduced its growth appreciably and favoured the growth of the component crops.

5.2 Productivity of sweet potato, soybean, maize and pigeonpea

In the experiment on intercropping of sweet potato and soybean, the sweet potato yields, in the intercropping arrangement of 1 : 1 ratio of alternate rows 60 cm apart under simultaneous planting, were as good as the yields under sole cropping of sweet potato. Under this intercropping system, soybean yields were reduced by 46 to 56 % as compared to that in the sole cropping, mainly because of the fact that the plant population of soybean was 62 % less under this cropping system as compared to that of sole crop. The soybean yields, ranging from 937 to 1450 kg / ha in different years, were the added advantages over the yield of sweet potato, which were as good as those recorded under the sole cropping of sweet potato. This was further confirmed in the second experiment, where the added advantage of soybean yield ranged from 907 to 1417 kg / ha. On the other hand, simultaneously established soybean / sweet potato (cv. H-268) intercroppings under 1 : 1 alternate rows 30 cm apart, 28 : 1SP and 2 : 2 alternate paired rows arrangements, produced 149 to 255, 165 to 232 and 221 to 273 q / ha of tuber, respectively, and 1561 to 1979 kg / ha of soybean grain yields. From the available literature no information could be available on the intercropping of soybean with sweet potato; but a number of workers have reported of reduction in soybean yield due to intercropping with other crops like maize (Reddy and Chatterjee, 1976a; Galal et al., 1980;

Mohta and De, 1980), pigeonpea (Saxena et al., 1977), sorghum (Reddy and Chatterjee, 1974; Mohta and De, 1980), wheat and oat (Chan et al., 1980) and sugarcane (Chandra, 1978).

In the second experiment, intercropping of maize with sweet potato, both planted in mid-July, recorded the yield of sweet potato, 10 to 38 % more than that recorded under sole cropping (328 to 421 q / ha). Quite possible that the available resources (light, moisture and nutrients, particularly) could be better utilised by sweet potato under maize / sweet potato intercropping than in the sole cropping of sweet potato. Maize yield (3008 to 3765 kg / ha) under this intercropping system ranged from 64 to 89 % of the sole crop yield of maize and this was an additional advantage over the equivalent or slightly higher yields of sweet potato (cv. H-268 and Pusa Safed) recorded under sole cropping. When sweet potato was planted in between the rows of maize (120 cm apart) at 45 days after sowing of maize, there was slight reduction (8 %) in maize yield and the sweet potato yield was 90 % of the sole crop. Ahlawat and Samlal (1979) and Akhanda (1979) reported that maize yields were not affected due to intercropping with sweet potato, but tuber yields were reduced. In the present investigation, short duration (95 days) maize cv. Diara Composite under wider (120 cm) row spacing did not affect sweet potato yield.

In the intercroppings of soybean / sweet potato and maize / sweet potato (in 1 : 1 alternate rows 60 cm apart), the availability of light at the top of the sweet potato canopy was as good as that under sole crop of sweet potato (Table 5.1) from 97 and 120 days after sowing of maize / sweet potato and soybean / sweet potato

intercroppings, respectively (maize and soybean were harvested at 95 and 110 - 115 days after sowing, respectively). Gollifer (1980) reported that the tuber yield was positively correlated with the mean solar radiation receipts during the period from 1 to 3 months before harvesting of sweet potato. As recorded by other workers (Willey and Osiru, 1972; IRRI, 1974, 1975; Kundu and Chatterjee, 1982), it was observed in this experiment also (Fig. 5.3) that wider were the differences between the maturity of the two companion crops lesser were the yield reductions in the sweet potato crop. There was close positive correlation between the differences in maturity of component crops and the tuber yields of sweet potato (r = 0.95 to 0.99). Pigeonpea, because of its late growth habit depressed severely the productivity of sweet potato.

Table 5.1 Percentage of sunlight available on the top of the sweet potato canopy under different cropping systems (planted simultaneously) : Experiment number 2c (1980 - 81)

Cropping	Days after planting					
	76	97	120	148	212	240
Sweet potato cv. H-268						
Sole sweet potato	100.0	100.0	100.0	100.0	100.0	100.0
Soybean / sweet potato	86.4	65.5	100.0	100.0	100.0	100.0
Maize / sweet potato	65.8	100.0	100.0	100.0	100.0	100.0
Pigeonpea / sweet potato	70.4	22.4	12.9	10.8	12.3	31.3
Sweet potato cv. Pusa Safed						
Sole sweet potato	100.0	100.0	100.0	100.0	100.0	100.0
Soybean / sweet potato	84.2	63.6	100.0	100.0	100.0	100.0
Maize / sweet potato	65.7	100.0	100.0	100.0	100.0	100.0
Pigeonpea / sweet potato	68.4	21.0	16.4	9.7	13.2	40.2

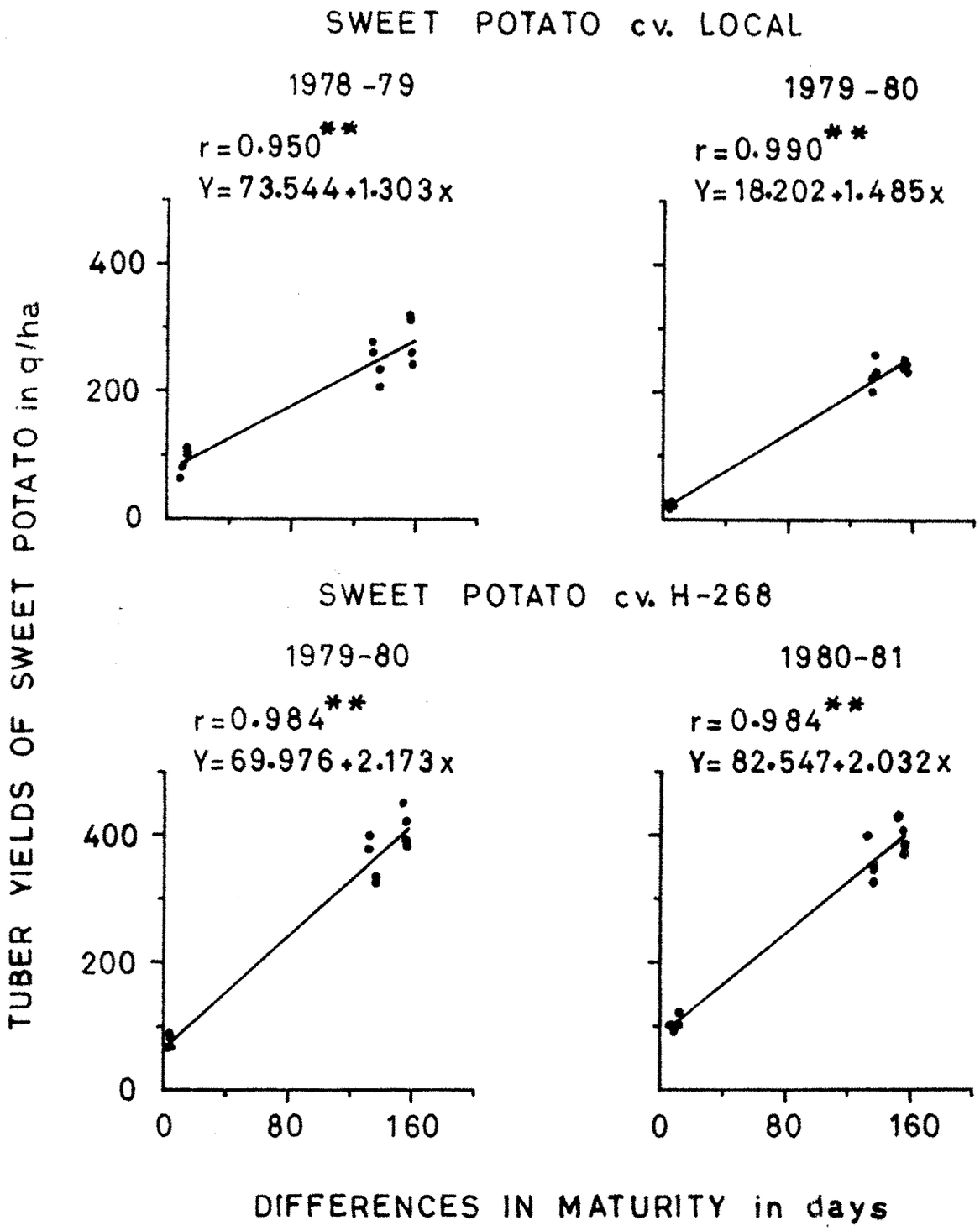

Fig.5.3 RELATIONS BETWEEN DIFFERENCES IN MATURITY OF COMPONENT CROPS AND TUBER YIELDS OF SWEET POTATO

5.3 Land Equivalent Ratio (LER)

The LER values, calculated on the basis of sole crop yields sown or planted in July, indicated yield advantages to the tune of 70 % from soybean / sweet potato intercroppings. The advantages were comparatively low (total LER = 1.27) with local variety of sweet potato having low-yield potentiality. When soybean and sweet potato established simultaneously, comparatively high yield advantages (total LER values ranging from 1.26 to 1.55) were obtained under 1 : 1 arrangement (rows 60 cm apart). The other spatial arrangements, viz. 2 : 2 alternate paired rows, 2S : 1SP and 1 : 1 alternate rows 30 cm apart also recorded total LER values of 1.20 to 1.70, 1.17 to 1.62 and 1.06 to 1.61, respectively, and indicated yield advantages mainly due to high LER values of soybean. Under relay planting situations also, the intercroppings proved to be superior to respective sole crops of sweet potato, which yielded low due to late planting.

Under any spatial arrangement of soybean / sweet potato intercroppings, delay in planting of sweet potato caused the competition in favour of soybean (Fig. 5.4). Diagonal lines, joining the two axes of Fig. 5.4, showed that the yield advantages increased when the competition tended to go in favour of sweet potato. In 1 : 1 alternate rows 60 cm apart arrangement, competition was in favour of sweet potato under simultaneous planting and also when planting of sweet potato was delayed by 45 days during 1978 - 79. The above intercropping arrangement exhibited 1 : 1 equal competition, when sweet potato was planted at 45 days after sowing of soybean during 1977 - 78 and 1978 - 79. Planting of sweet potato simultaneously with soybean, under 2 : 2 alternate paired row arrangement during

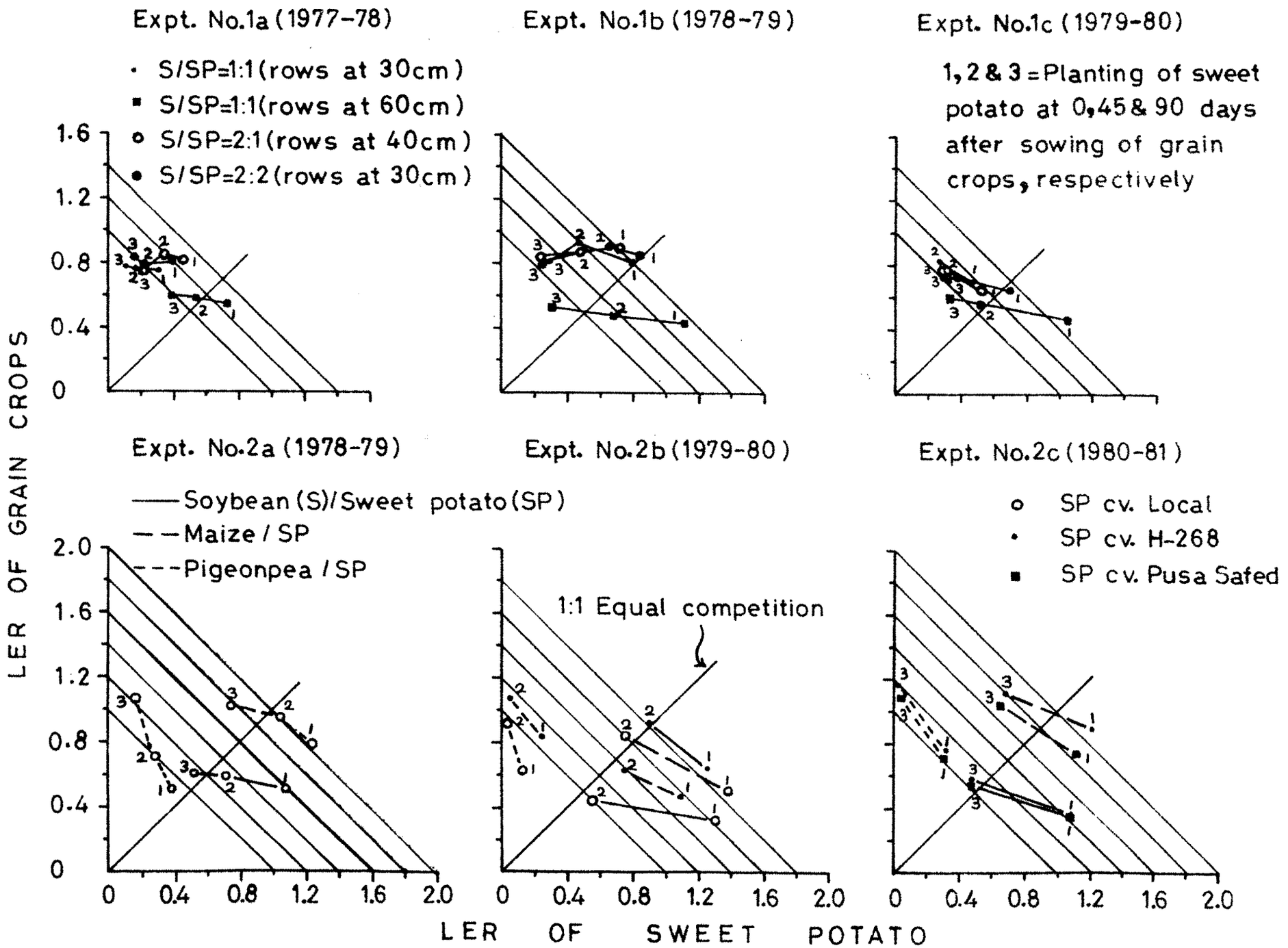

Fig. 5.4 LAND EQUIVALENT RATIO (LER) DIAGRAM

1978 - 79 and 1979 - 80 and under 1 : 1 row arrangement with narrow (30 cm) row spacing during 1978 - 79 also showed 1 : 1 equal competition. In all other intercropping situtations, competitions were in favour of soybean.

The intercropping of maize and sweet potato, established simultaneously, produced high yield advantages and recorded total LER values of 1.85 to 2.10. Appreciable yield advantages (total LER = 1.61 to 2.00) were also achieved from this intercropping, when sweet potato was planted at 45 days after sowing of maize. High yield advantages were similarly reported, when Setaria (100 %) and pearl millet (83 %) were intercropped with pigeonpea, in the semi-arid tropics at Hyderabad (ICRISAT, 1976).

In maize / sweet potato intercropping, competition was in favour of sweet potato, when both were established simultaneously (Fig. 5.4). When planting of sweet potato was delayed by 45 days, maize and sweet potato showed equal (50 : 50) competition. Planting of sweet potato at 90 days after sowing of maize caused competition in favour of maize. Early planting of sweet potato, when grown in association with soybean or maize, favoured sweet potato crop and increased the LER values of sweet potato, which in turn increased the total LER values. On the other hand, in pigeonpea / sweet potato intercropping, the competition was always in favour of pigeonpea crop, the magnitude increased with the delay in planting of sweet potato. In contrast to the other two intercroppings, in pigeonpea / sweet potato intercropping the total LER values increased slightly above 1.0 (i.e.,low yield advantage), when competition in favour of pigeonpea increased with the delay in planting of sweet potato.

5.4 Competitions in intercropping and yield advantages

Changes in the Competitive Ratio (CR) of sweet potato under different spatial arrangements in relation to different timings of planting of sweet potato, in the Experiment number 1 (Fig. 5.5), indicated that the competitive ability of sweet potato was maximum under early planting situation, and decreased with the delay in planting. Although the values differed in different years, the relative positions of different spatial arrangements in terms of competitive ability of the component crops, were, more or less, maintained at different intercropping situations. The competitive ability of sweet potato crop was maximum under 1 : 1 arrangement with rows 60 cm apart and this ability decreased in the order 2S : 1SP (rows 40 cm apart), 2 : 2 alternate paired rows (30 cm apart) and 1 : 1 (rows 30 cm apart) arrangements. The competitive ability was high in high-yielding variety of sweet potato cv. H-268.

Studies on the relations between yield advantages (i.e., total LER) and the Competitive Ratios of sweet potato (Table 5.2; Fig. 5.6) indicated that there was close positive correlation between them under different spatial arrangements. Yield advantages increased with increase in the CR values of sweet potato under all spatial arrangements. Again, the CR values of sweet potato increased with early planting of sweet potato. This is an indication, that in soybean / sweet potato intercroppings, yield advantages may be increased by increasing the competitive ability (i.e., the dominance) of sweet potato.

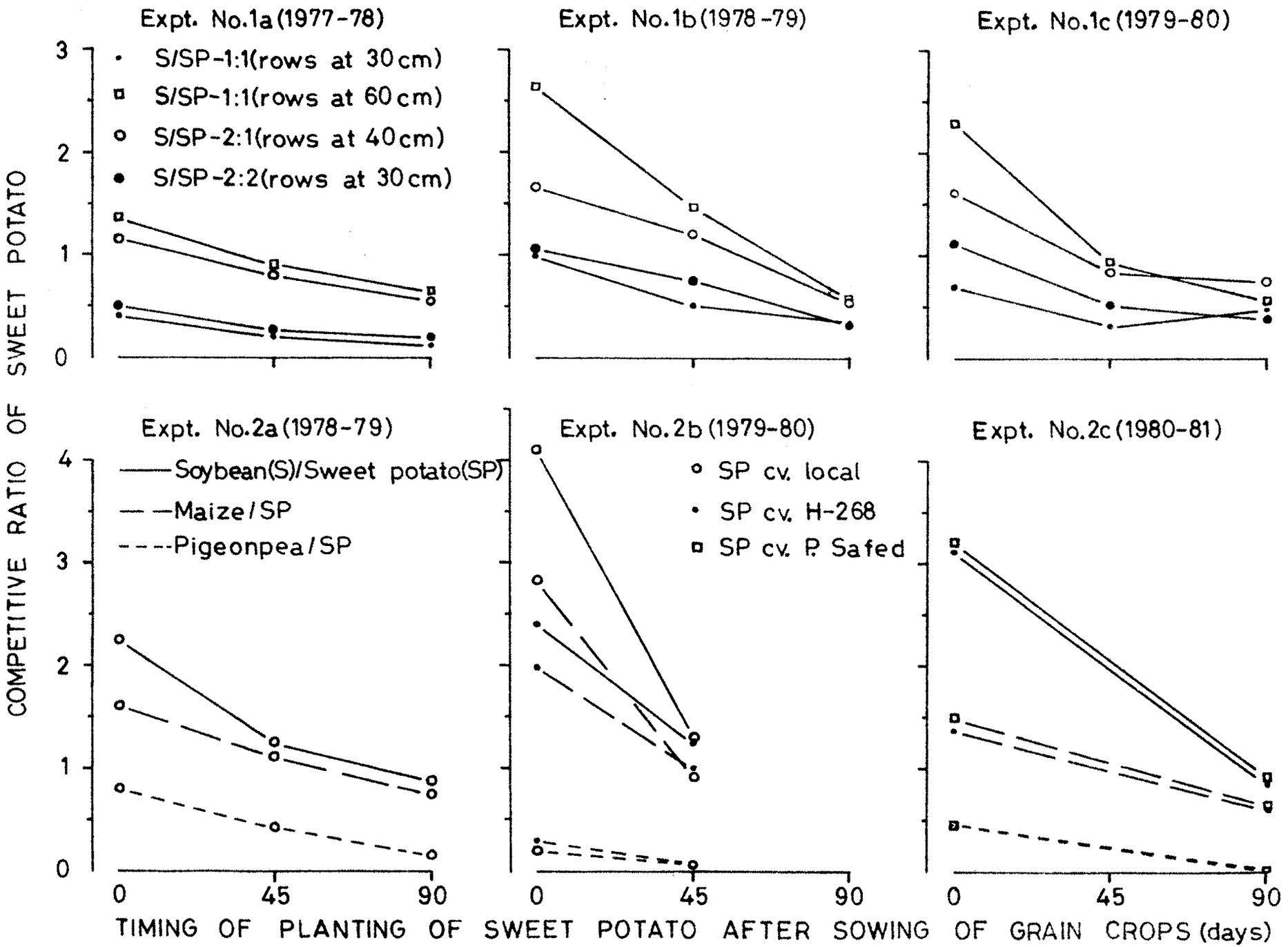

Fig.5.5 COMPETITIVE RATIO OF SWEET POTATO UNDER DIFFERENT INTERCROPPING SYSTEMS

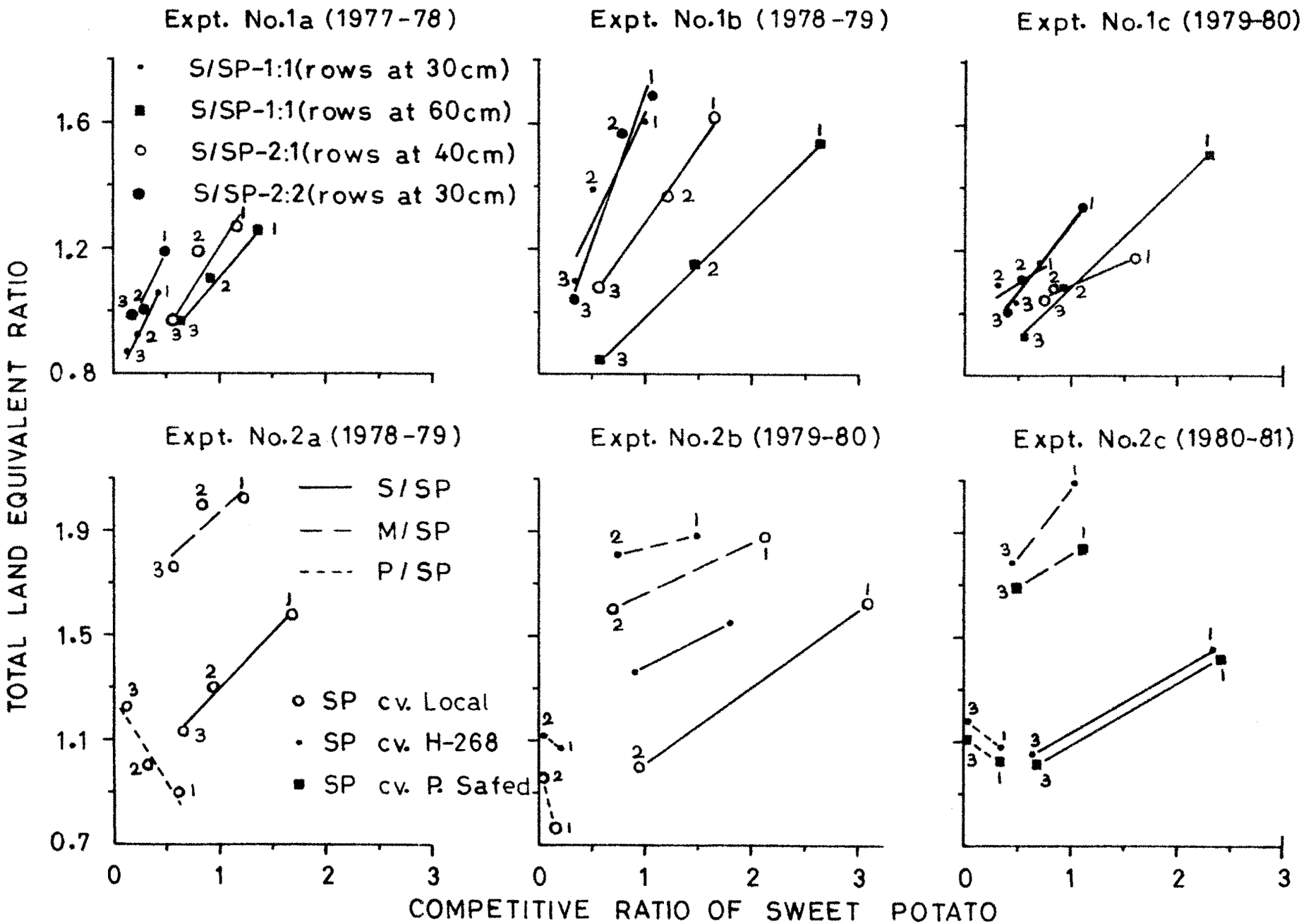

Fig. 5.6 RELATIONS BETWEEN YIELD ADVANTAGES AND COMPETITIVE RATIOS OF SWEET POTATO (S=Soybean M=Maize P=Pigeonpea SP=Sweet potato 1,2&3=Planting of sweet potato at 0,45&90 days after sowing of grain crops, respectively)

Table 5.2 Relations between total LER (Y) and Competitive Ratio of sweet potato (X) : Experiment number 1a, b and c

Spatial arrangement	Correlation coefficient (r) values	Regression equations Y =
Experimental number 1a (1977 - 78)		
S / SP - 1 : 1 (rows at 30 cm)	0.999	0.785 + 0.649 x
S / SP - 1 : 1 (rows at 60 cm)	0.990	0.721 + 0.398 x
S / SP - 2 : 1 (rows at 40 cm)	0.942	0.717 + 0.502 x
S / SP - 2 : 2 (rows at 30 cm)	0.980	0.820 + 0.768 x
Experiment number 1b (1978 - 79)		
S / SP - 1 : 1 (rows at 30 cm)	0.925	0.927 + 0.715 x
S / SP - 1 : 1 (rows at 60 cm)	0.999	0.650 + 0.337 x
S / SP - 2 : 1 (rows at 40 cm)	0.998	0.792 + 0.491 x
S / SP - 2 : 2 (rows at 30 cm)	0.981	0.761 + 0.943 x
Experiment number 1c (1979 - 80)		
S / SP - 1 : 1 (rows at 30 cm)	0.610	0.991 + 0.205 x
S / SP - 1 : 1 (rows at 60 cm)	0.999	0.755 + 0.330 x
S / SP - 2 : 1 (rows at 40 cm)	0.955	0.960 + 0.132 x
S / SP - 2 : 2 (rows at 30 cm)	0.991	0.854 + 0.442 x

S = Soybean, SP = Sweet potato

Changes in the CR values of sweet potato under different intercroppings in relation to different timings of planting of sweet potato, as recorded under Experiment number 2 (Fig. 5.5), further confirmed that under simultaneous establishement of two crops, sweet potato had maximum competitive ability which decreased with the delay in planting. The competitive ability of sweet potato was maximum under soybean / sweet potato intercropping,

followed by maize / sweet potato and pigeonpea / sweet potato intercroppings. Local variety of sweet potato, due to its more viny growth habit, appeared to be more competitive than the high-yielding variety cv. H-268, particularly when grown with soybean or maize. The two high-yielding varieties behaved, more or less, similarly.

Studies on the relations between yield advantages and CR values of sweet potato, in Experiment number 2 (Table 5.3; Fig. 5.6), indicated high positive correlation between them, when sweet potato was intercropped with soybean or maize. But there was high negative correlation under pigeonpea / sweet potato intercropping. It can be perused from Fig. 5.6 that when sweet potato was intercropped with soybean or maize, yield advantages

Table 5.3 Relations between total LER (Y) and Competitive Ratio of sweet potato (X) : Experiment number 2a (1978 - 79)

Intercropping	Correlation co-efficient (r) value	Regression equation Y =
Soybean / sweet potato	0.994	0.873 + 0.319 x
Maize / sweet potato	0.884	1.592 + 0.292 x
Pigeonpea / sweet potato	-0.960	1.266 - 0.493 x

increased with increasing competitive ability of sweet potato, which in turn, increased with early planting of sweet potato. The situation was quite opposite under pigeonpea / sweet potato intercropping and the yield advantage increased slightly when the CR values of sweet potato were reduced due to delayed planting.

The local variety of sweet potato was less efficient than cv. H-268 in increasing yield advantage, as at a particular CR value of sweet potato, during 1979 - 80 (Fig. 5.6), much higher yield advantage was obtained with cv. H-268. Superiority of cv. H-268 over cv. Pusa Safed, in this respect, was not so prominent except in maize / sweet potato intercropping, during 1980 - 81.

5.5 Monetary advantage in intercropping

Monetary advantages calculated on the basis of LER values indicated that these were mainly affected by sweet potato crop with high production potentiality (Table 5.4, 5.5). Monetary advantages were comparatively lower with local variety of sweet potato due to its lower productivity than the high-yielding varieties. In soybean / sweet potato intercroppings (Table 5.4), highest monetary return (Rs. 4,603/- to Rs.14,124/- per hectare) was obtained, when the crops were established simultaneously under 1 : 1 arrangement with wider (60 cm) row spacing. The wide range of variability was due to the appreciable differences in the productivity of local variety as compared to that of high-yielding variety. Intercropping arrangement of 1 : 1 alternate rows (30 cm apart) was observed to be remunerative (Rs.1,136/- to Rs.9,912/- per hectare),when sweet potato cv. H-268 was grown simultaneously with soybean. Under simultaneous planting situation, in other two arrangements (2S : 1SP and 2 : 2 alternate paired rows) the advantages ranged from Rs.1,283/- to Rs.11,534/- per hectare in three years. When sweet potato was planted at 45 days after sowing of soybean the monetary advantages were reduced. Monetary disadvantages, as indicated by the negative values, were recorded in 1 : 1 (30 cm apart rows)

Table 5.4 Monetary advantage (Rs. / ha) : Experiment number 1a, b and c

Treatment	1977-78			1978-79			1979-80		
	S	SP	Total	S	SP	Total	S	SP	Total
SP planted at 0 DAS									
Sole SP	-	-	-	-	-	-	-	-	-
S/SP 1:1(rows at 30 cm)	2696	-3562	- 866	2740	7172	9912	1850	- 714	1136
S/SP 1:1(rows at 60 cm)	430	4173	4603	- 610	14734	14124	- 391	12964	12573
S/SP 2:1(rows at 40 cm)	1509	2464	3973	2023	9404	11427	- 197	4510	4313
S/SP 2:2(rows at 30 cm)	3337	-2054	1283	3092	8442	11534	1366	4727	6093
SP planted at 45 DAS									
Sole SP		-2456	-2456		-4096	-4096		-4707	-4707
S/SP 1:1(rows at 30 cm)	2794	-6126	-3332	3806	- 710	3096	3233	-5697	-2464
S/SP 1:1(rows at 60 cm)	862	562	1424	- 268	4322	4054	589	476	1065
S/SP 2:1(rows at 40 cm)	1934	191	2125	1774	3882	5656	972	- 234	738
S/SP 2:2(rows at 30 cm)	3128	-5611	-2483	3823	3886	7709	2240	-2793	- 553
SP planted at 90 DAS									
Sole SP		-8011	-8011		-10918	-10918		-12839	-12839
S/SP 1:1(rows at 30 cm)	2921	-7000	-4079	2746	-5329	-2583	2039	-4289	-2250
S/SP 1:1(rows at 60 cm)	969	-2250	-1281	266	-4549	-4283	975	-4001	-3026
S/SP 2:1(rows at 40 cm)	866	-2268	-1402	1504	-2133	- 629	882	-1183	- 301
S/SP 2:2(rows at 30 cm)	3551	-6309	-2758	2543	-6000	-3457	2242	-5131	-2889

S = Soybean, SP = Sweet potato, DAS = Days after sowing of soybean

Table 5.5 Monetary advantage (Rs. / ha) : Experiment number 2a, b and c

Treat-ment	1978-79			1979-80			1980-81		
	S/M/P	SP	Total	S/M/P	SP	Total	S/M/P	SP	Total
SP planted at 0 DAS									
Sole SP_1		-	-		-	-		-	-
S/SP_1				-471	14539	14068	-1333	14340	13007
M/SP_1				1645	18450	20095	5183	17521	22704
P/SP_1				1713	-6245	-4532	1477	-4368	-2891
SP planted at 45 DAS									
Sole SP_1					-4957	-4957			
S/SP_1				1419	6130	7549			
M/SP_1				4925	9805	14730			
P/SP_1				2877	-9702	-6825			
SP planted at 90 DAS									
Sole SP_1								-11741	-11741
S/SP_1							816	-495	321
M/SP_1							6434	4450	10884
P/SP_1							3742	-10488	-6746
SP planted at 0 DAS									
Sole SP_2		-	-		-	-		-	-
S/SP_2	111	9834	9945	-2156	10501	8345	-1555	17895	16340
M/SP_2	3013	12570	15583	-	11479	11479	2539	19155	21694
P/SP_2	42	-1878	-1836	654	4893	-4239	1197	-6033	-4836
SP planted at 45 DAS									
Sole SP_2		-1354	-1354		-5770	-5770			
S/SP_2	1011	3550	4561	-716	652	-64			
M/SP_2	4678	9347	14025	4005	3506	7511			
P/SP_2	884	-3598	-2714	2113	-6611	-4498			
SP planted at 90 DAS									
Sole SP_2		-7173	-7173					-15703	-15703
S/SP_2	1235	340	1575				409	-631	-222
M/SP_2	5417	4270	9687				5706	4735	10441
P/SP_2	2389	-5646	-3257				3299	-16403	-13104

S = Soybean, M= Maize, P = Pigeonpea, SP_1 = Sweet potato cv. H-268, SP_2 = Sweet potato cv. Local (1978-79 and 1979-80), cv. Pusa Safed (1980-81), DAS = Days after sowing of grain crops

and 2 : 2 alternate paired rows arrangements, during 1977 - 78 and 1979 - 80. When sweet potato was planted at 90 days after sowing of soybean all the values were negative. However, the intercroppings with relay planted sweet potato, which seemed to be disadvantageous as compared to sole crops planted at first date, were advantageous over respective sole crops of sweet potato.

Highest monetary advantage (Rs.15,583/- to Rs.20,095/- per hectare) was obtained from maize / sweet potato intercropping established simultaneously (Table 5.5), followed by maize / sweet potato, planted at 45 days after sowing of maize (Rs.7,511/- to Rs.14,730/- per hectare), simultaneously established soybean / sweet potato (Rs.8,345/- to Rs.16,340/- per hectare) and maize / sweet potato planted at 90 days after sowing of maize (Rs.9,687/- to Rs.10,884/- per hectare) intercroppings. Pigeonpea / sweet potato intercroppings indicated monetary disadvantages. The valuation of the sole crop yields of soybean, maize, pigeonpea and sweet potato (high-yielding varieties) ranged from Rs.8,844/- to Rs.11,852/-, Rs.10,470/- to Rs.11,823/-, Rs.4,200/- to Rs.5,692/- and Rs.23,687/- to Rs.31,578/- per hectare, respectively in different years. Cost of production of the experimental crops have been presented in Appendix II.

5.6 Calorie return

In terms of calorie equivalents of grain and tuber yields per hectare, intercropping system of simultaneously established soybean / sweet potato under 1 : 1 arrangement with wider (60 cm) row spacing only recorded higher calorie production (47.04 to

61.93 million cal / ha over that of sweet potato sole cropping (cv. H-268 and Pusa Safed),planted at the time of sowing of soybean (Table 5.6, 5.8, 5.9). Intercroppings failed to produce higher calorie return than sole crop of sweet potato during 1977 - 78, when local variety of sweet potato was used.

Maize / sweet potato (cv. H-268 and Pusa Safed) intercroppings under simultaneous establishment (Table 5.7, 5.8, 5.9) produced maximum calorie (64.41 to 72.07 million cal / ha). Intercropping of maize with sweet potato planted at 45 days after sowing of maize also produced more calorie than sole crop of sweet potato, planted at the time of sowing of grain crops. Pigeonpea / sweet potato intercropping was inefficient in this respect. The calorie values of the grains / tubers of sole crops of soybean, maize, pigeonpea and sweet potato were 6.85 to 9.18, 14.53 to 16.18, 3.78 to 4.27 and 41.69 to 55.58 million calories per hectare, respectively.

Table 5.6 Calorie production (million cal / ha) : Experiment number 1a, b and c

Treatment	1977-78			1978-79			1979-80		
	S	SP	Total	S	SP	Total	S	SP	Total
Sole S	8.35		8.35	6.85		6.85	7.59		7.59
Sweet potato planted at 0 DAS									
Sole SP		33.28	33.28		42.38	42.38		41.69	41.69
S/SP 1:1 (rows at 30 cm)	6.26	10.23	16.49	5.55	33.66	39.21	5.21	19.69	24.90
S/SP 1:1 (rows at 60 cm)	4.49	24.04	28.53	2.91	47.19	50.10	3.48	43.56	47.04
S/SP 2:1 (rows at 40 cm)	6.76	15.35	22.11	6.14	30.55	36.69	4.95	21.73	26.68
S/SP 2:2 (rows at 30 cm)	6.76	12.81	19.57	5.82	36.08	41.90	4.84	29.12	33.96
Sweet potato planted at 45 DAS									
Sole SP		28.93	28.93		35.20	35.20		33.14	33.14
S/SP 1:1 (rows at 30 cm)	6.32	5.56	11.88	6.38	19.58	25.96	6.30	10.86	17.16
S/SP 1:1 (rows at 60 cm)	4.84	17.49	22.33	3.25	28.74	31.99	4.26	21.78	26.04
S/SP 2:1 (rows at 40 cm)	7.08	11.44	18.52	5.98	20.93	26.91	5.80	13.14	18.94
S/SP 2:2 (rows at 30 cm)	6.60	7.15	13.75	6.14	28.22	34.36	5.48	15.57	21.05
Sweet potato planted at 90 DAS									
Sole SP		19.47	19.47		23.49	23.49		19.26	19.26
S/SP 1:1 (rows at 30 cm)	6.46	3.08	9.54	5.55	11.94	17.49	5.34	13.42	18.76
S/SP 1:1 (rows at 60 cm)	4.92	12.54	17.46	3.64	13.06	16.70	4.52	13.67	18.19
S/SP 2:1 (rows at 40 cm)	6.30	6.98	13.28	5.76	10.01	15.77	5.77	11.66	17.43
S/SP 2:2 (rows at 30 cm)	6.95	5.20	12.15	5.37	10.56	15.93	5.51	11.50	17.01
S. Em ±	0.439	1.483	1.572	0.458	1.901	1.868	0.333	1.650	1.648
C.D.5%	1.265	4.281	4.539	1.304	5.488	5.394	0.961	4.764	4.758
S.A. x T.P.	NS	*	NS	NS	**	**	NS	**	**

Table 5.6 (continued)

Treatment	1977-78			1978-79			1979-80		
	S	SP	Total	S	SP	Total	S	SP	Total
Spatial arrangement of sweet potato (S.A.)									
Sole SP		27.23	27.23		33.69	33.69		31.36	31.36
S/SP 1:1 (rows at 30 cm)	6.35	6.29	12.64	5.83	21.72	27.55	5.61	14.66	20.27
S/SP 1:1 (rows at 60 cm)	4.75	18.02	22.77	3.26	29.67	32.93	4.09	26.34	30.43
S/SP 2:1 (rows at 40 cm)	6.71	11.26	17.97	5.96	20.50	26.46	5.51	15.51	21.02
S/SP 2:2 (rows at 30 cm)	6.75	8.40	15.15	5.78	24.95	30.73	5.28	18.72	24.00
S. Em ±	0.253	0.856	0.907	0.261	1.097	1.078	0.191	0.953	0.951
C.D.5%	0.728	2.471	2.619	0.754	3.167	3.113	0.553	2.750	2.746
Timing of planting of sweet potato (T.P.)									
0 DAS	6.07	19.14	23.99	5.10	37.97	42.05	4.62	31.16	34.85
45 DAS	6.21	14.11	19.08	5.44	26.53	30.88	5.47	18.90	23.27
90 DAS	6.15	9.46	14.38	5.08	13.81	17.87	5.29	13.90	18.13
S. Em ±	0.222	0.664	0.703	0.227	0.850	0.835	0.165	0.738	0.737
C.D.5%	NS	1.918	2.030	NS	2.455	2.411	0.478	2.131	2.128

S = Soybean, SP = Sweet potato, DAS = Days after sowing of soybean,
NS = Not significant, * and ** = Significant at 5 % and 1 %, respectively

Table 5.7 Calorie production (million cal / ha) : Experiment number 2a (1978 - 79)

Treatment	Soy-bean	Maize	Pigeon -pea	Sweet potato	Total
Sole soybean	8.70				8.70
Sole maize		14.32			14.32
Sole pigeonpea			3.15		3.15
Sweet potato planted at 0 DAS					
Sole sweet potato				29.98	29.98
Soybean / sweet potato	4.39			32.23	36.62
Maize / sweet potato		11.23		37.07	48.30
Pigeonpea / sweet potato			1.60	11.72	13.32
Sweet potato planted at 45 DAS					
Sole sweet potato				27.39	27.39
Soybean / sweet potato	5.14			21.12	26.26
Maize / sweet potato		13.51		31.41	44.92
Pigeonpea / sweet potato			2.24	8.74	10.98
Sweet potato planted at 90 DAS					
Sole sweet potato				17.44	17.44
Soybean / sweet potato	5.30			15.57	20.87
Maize / sweet potato		14.54		22.55	37.09
Pigeonpea / sweet potato			3.36	4.68	8.04
S. Em ±	0.315	0.570	0.110	1.844	1.721
C. D. at 5 %	1.007	1.824	0.350	5.309	4.969
Cropping with sweet potato					
Sole sweet potato				24.93	24.93
Soybean / sweet potato				22.97	27.92
Maize / sweet potato				30.34	43.43
Pigeonpea / sweet potato				8.38	10.78
S. Em ±				1.065	0.994
C. D. at 5 %				3.065	2.870
Timing of planting of sweet potato					
0 DAS				27.75	32.05
45 DAS				22.17	27.39
90 DAS				15.06	20.86
S. Em ±				0.922	0.860
C. D. at 5 %				2.653	2.483

DAS = Days after sowing of grain crops

Table 5.8 Calorie production (million cal / ha) : Experiment number 2b (1979 - 80)

Treatment	Soy-bean	Maize	Pigeon -pea	Sweet potato	Total
Sole soybean	9.18				9.18
Sole maize		16.18			16.18
Sole pigeonpea			3.78		3.78
Sweet potato planted at 0 DAS					
Sole SP_1				43.31	43.31
Soybean / SP_1	4.20			47.27	51.47
Maize / SP_1		10.29		54.12	64.41
Pigeonpea / SP_1			3.18	10.15	13.33
Sweet potato planted at 45 DAS					
Sole SP_1				34.90	34.90
Soybean / SP_1	5.68			32.37	38.05
Maize / SP_1		14.76		38.83	53.59
Pigeonpea / SP_1			4.05	1.90	5.95
Sweet potato planted at 0 DAS					
Sole SP_2				23.05	23.05
Soybean / SP_2	2.97			30.03	33.00
Maize / SP_2		8.07		31.68	39.75
Pigeonpea / SP_2			2.38	3.02	5.40
Sweet potato planted at 45 DAS					
Sole SP_2				12.93	12.93
Soybean / SP_2	4.07			12.62	16.69
Maize / SP_2		13.53		17.60	31.13
Pigeonpea / SP_2			3.47	0.74	4.21
S. Em ±	0.338	0.450	0.178	2.127	1.988
C. D. at 5 %	1.043	1.388	0.548	6.064	5.740

Table 5.8 (continued)

Treatment	Soy-bean	Maize	Pigeon-pea	Sweet potato	Total
Sweet potato variety					
SP_1 = cv. H-268	4.94	12.52	3.61	32.86	38.12
SP_2 = cv. Local	3.52	10.80	2.92	16.46	20.77
S. Em ±	0.240	0.319	0.125	0.752	0.703
C. D. at 5 %	0.741	0.983	0.385	2.145	2.030
Cropping with sweet potato					
Sole sweet potato				28.55	28.55
Soybean / sweet potato				30.57	34.80
Maize / sweet potato				35.56	47.22
Pigeonpea / sweet potato				3.95	7.22
S. Em ±				1.064	0.994
C. D. at 5 %				3.033	2.870
Timing of planting of sweet potato					
0 DAS	3.58	9.18	2.78	30.33	34.21
45 DAS	4.88	14.14	3.76	18.98	24.68
S. Em ±	0.240	0.319	0.125	0.752	0.703
C. D. at 5 %	0.741	0.983	0.385	2.145	2.030

DAS = Days after sowing of grain crops

Table 5.9 Calorie production (million cal / ha) : Experiment number 2c (1980 - 81)

Treatment	Soy-bean	Maize	Pigeon -pea	Sweet potato	Total
Sole soybean	7.99				7.99
Sole maize		14.53			14.53
Sole pigeonpea			4.27		4.27
Sweet potato planted at 0 DAS					
Sole SP_1				43.42	43.42
Soybean / SP_1	2.93			47.00	49.93
Maize / SP_1		12.88		52.55	65.43
Pigeonpea / SP_1			3.24	13.67	16.91
Sweet potato planted at 90 DAS					
Sole SP_1				22.39	22.39
Soybean / SP_1	4.58			20.88	25.46
Maize / SP_1		16.02		29.59	45.61
Pigeonpea / SP_1			4.93	0.78	5.71
Sweet potato planted at 0 DAS					
Sole SP_2				55.58	55.58
Soybean / SP_2	2.80			59.13	61.93
Maize / SP_2		10.72		61.35	72.07
Pigeonpea / SP_2			3.04	17.33	20.37
Sweet potato planted at 90 DAS					
Sole SP_2				27.64	27.64
Soybean / SP_2	4.27			26.62	30.89
Maize / SP_2		15.03		36.11	51.14
Pigeonpea / SP_2			4.61	1.84	6.45
S. Em ±	0.354	0.530	0.148	3.192	2.997
C. D. at 5 %	1.090	1.633	0.455	9.100	8.654

Table 5.9 (continued)

Treatment	Soy-bean	Maize	Pigeon -pea	Sweet potato	Total
Sweet potato variety					
SP_1 = cv. H-268	3.76	14.45	4.09	28.78	34.36
SP_2 = cv. Pusa Safed	3.54	12.87	3.82	35.70	40.76
S. Em ±	0.250	0.376	0.105	1.129	1.060
C. D. at 5 %	NS	1.160	NS	3.218	3.061
Cropping with sweet potato					
Sole sweet potato				37.26	37.26
Soybean / sweet potato				38.40	42.05
Maize / sweet potato				44.90	58.56
Pigeonpea / sweet potato				8.40	12.36
S. Em ±				1.596	1.498
C. D. at 5 %				4.550	4.325
Timing of planting of sweet potato					
0 DAS	2.87	11.79	3.14	43.75	48.20
90 DAS	4.43	15.53	4.77	20.73	26.91
S. Em ±	0.250	0.376	0.105	1.129	1.060
C. D. at 5 %	0.772	1.160	0.323	3.218	3.061

DAS = Days after sowing of grain crops, NS = Not significant

6. FUTURE SCOPE OF WORK

There is further scope of expanding the work on resource utilisation under intercroppings of two crops as compared to their sole croppings by analysing the photosynthetically active radiations (PAR) reaching at different levels of component crop canopies, under different geometrical patterns of crop establishment. Further, in future some trials need to be undertaken for studying the growth and productivity of the intercrops under various levels and methods of fertilizer applications. This will give some useful scientific informations on the competition between two crops for nutrients. Limitation in irrigation water supply is an important constraint in Indian Agriculture. The productivity of the promising intercropping systems, evolved in this work, need to be looked into under rainfed conditions as compared to their productivity under limited and adequate levels of irrigation. Under experimental condition all the operations were mostly done manually in small plots. A more clear picture of its cost of production and feasibility of carrying out many cultural operations like weeding, lifting of vines (for reducing indiscriminate rootings) and earthing up of maize, can be achieved after establishing such intercroppings in big plots (at least 1000 sq.m.). Weevil is an important pest of sweet potato. The studies on the effects of intercrops on the weevil damage of tubers, under different plant protection measures, will be an interesting field of study.

7. SUMMARY AND CONCLUSION

A number of field experiments were conducted to analyse the growth and productivity of crops, (i) in one series, on the intercropping of sweet potato with soybean under different spatial arrangements and timings of planting of sweet potato, and (ii) in another series, on the intercropping of sweet potato at a fixed spatial arrangement, but with crops of different growth habits (soybean, maize and pigeonpea) under different timings of planting of sweet potato, as compared to their productivity under sole croppings, in Randomised Block Design with four replications during the years from 1977 - 78 to 1980 - 81.

Bio-mass production per unit area in soybean (cv. Bragg) was reduced more (up to 60 %), when intercropped with sweet potato under the arrangement of 1 : 1 alternate rows 60 cm apart (both the crops established simultaneously), mainly because of decreased plant population. The reduction was less (18 to 32 %) under the other three spatial arrangements (2S : 1SP, 1 : 1 rows 30 cm apart and 2 : 2 alternate paired rows). The soybean growth was not affected under the latter three arrangements, when sweet potato was interplanted 45 days later than soybean. The growth of maize (cv. Diara Composite) and pigeonpea (cv. AS-8) was reduced, due to intercropping (under 1 : 1 alternate rows 60 cm apart) by 12 to 17 % and 18 to 25 %, respectively, only when grown simultaneously with sweet potato. When planted in July, the root tubers were initiated in early October and leaf growth increased between 150 and 200 days after planting. Under maize / sweet potato, followed by soybean / sweet potato intercroppings (in 1 : 1

alternate rows 60 cm apart arrangement), when both the crops were established simultaneously, sweet potato accumulated dry matter more efficiently than under sole cropping. Sweet potato canopies under those intercroppings intercepted light, more or less, equal to those intercepted under sole cropping, after harvesting (95 and 115 days after sowing of maize and soybean, respectively) of the component crops. When pigeonpea (220 - 240 days duration) was intercropped, availability of light on the sweet potato canopy was reduced and hence the growth of sweet potato was drastically reduced. It could intercept only 0 to 5 % solar radiation during the major period of growth of pigeonpea. Accumulation of dry matter in sweet potato plant was reduced by 20, 28 and 40 % when soybean and sweet potato were simultaneously established under 2 : 2 alternate paired rows, 2 : 1 and 1 : 1 (rows 30 cm apart) spatial arrangements, respectively; the light interception by sweet potato canopies were reduced accordingly. The growth of sweet potato was further reduced due to its late planting.

Yield potentiality of local variety of sweet potato was much lower than those of high-yielding varieties (cv. H-268 and Pusa Safed). Among the four spatial arrangements of soybean / sweet potato intercropping, 1 : 1 alternate rows (60 cm apart) arrangement recorded the highest yield. This arrangement, under simultaneous planting, produced tuber yields (330 to 448 q / ha with high-yielding varieties), similar to those recorded under sole croppings. In this intercropping system, the soybean grain yields were reduced by 46 to 65 % , but an added advantage of 907 to 1450 kg / ha of soybean grain yields could be achieved over sweet potato

yields, equivalent to the sole crop yields in different years. On the other hand, simultaneously established soybean / sweet potato (cv. H-268) intercroppings, under 1 : 1 alternate rows 30 cm apart, 2S : 1SP and 2 : 2 alternate paired rows arrangements, produced 149 to 255, 165 to 232 and 221 to 273 q / ha of tuber, respectively, and 1561 to 1979 kg / ha of soybean grain yields. Under simultaneously planted maize / sweet potato intercroppings, with plant population of the intercrops equal to that of sole cropping, sweet potato gave 398 to 465 q / ha of tuber yields, which was 11 to 25 % higher than under sole croppings of cv. H-268 and Pusa Safed. Maize grain yields to the tune of 3008 to 3765 kg / ha (64 to 89 % of sole crop yield of maize) was an additional advantage over the equivalent or slightly higher sweet potato yields obtained as sole crop. The above intercroppings with relay planted sweet potato were also beneficial over respective sole croppings of sweet potato. Sweet potato yields were reduced by 68 to 98 %, when pigeonpea was intercropped; the pigeonpea yields were 71 to 116 % of the sole crop yields. The total productivity of grains and tubers under intercroppings increased as the differences in the maturity of the two component crops widened.

Aggressivity of sweet potato (high-yielding varieties) was maximum in soybean / sweet potato intercropping (A_{sp} = 1.17 to 1.43), followed by maize / sweet potato intercropping (A_{sp} = 0.65 to 1.23), when the component crops were established simultaneously under 1 : 1 arrangement of rows 60 cm apart. Sweet potato was dominated by the component crop when pigeonpea was intercropped (A_{sp} ranging from -0.80 to -2.28).

The LER values for the combined yields of soybean (0.35 to 0.46) and sweet potato (1.05 to 1.11) ranged from 1.42 to 1.55 in soybean / sweet potato (high-yielding varieties) intercroppings, planted simultaneously under 1 : 1 arrangement of rows 60 cm apart. In this intercropping system, competition was in favour of sweet potato. Other spatial arrangements under simultaneous planting also recorded total LER values of 1.16 to 1.70, mainly due to high LER values of soybean (0.64 to 0.85). Intercroppings of maize with simultaneously established high-yielding varieties of sweet potato recorded LER values of maize 0.64 to 0.89 and of sweet potato 1.11 to 1.25, and thus produced 85 to 110 % yield advantages and the competition was in favour of sweet potato. A delay of 45 days in planting of sweet potato in the maize / sweet potato intercropping also recorded yield advantages up to 82 %. Intercropping of maize or soybean with relay planted sweet potato also proved to be advantageous, particularly over respective sole croppings of sweet potato. In both the maize / sweet potato and soybean / sweet potato intercroppings, the yield advantages increased when the intercrop competitions were in favour of sweet potato under simultaneous planting. Pigeonpea / sweet potato intercroppings recorded total LER values of 1.02 to 1.18; the slight yield advantage was mainly due to high LER values of pigeonpea (0.71 to 1.16).

Among the different spatial arrangements of soybean / sweet potato (high-yielding varieties) intercroppings, sweet potato was most competitive (CR_{sp} = 2.29 to 3.20) under 1 : 1 arrangement with rows 60 cm apart, when component crops were established

simultaneously. Sweet potato was more competitive (CR_{sp} = 1.37 to 1.98) than maize, only under simultaneous establishment. In pigeonpea / sweet potato intercropping, pigeonpea was always more competitive over sweet potato (CR_{sp} = 0.02 to 0.44). The CR values of sweet potato decreased with the delay in planting of sweet potato. The yield advantages in soybean / sweet potato and maize / sweet potato intercroppings, increased with increase in the CR values of sweet potato.

Monetary advantages (price of produce only) per hectare was maximum under maize / sweet potato intercropping (ranging from Rs.20,095/- to Rs.22,704/-), followed by soybean / sweet potato intercropping (from Rs.12,573/- to Rs.16,340/-), when high-yielding varieties of sweet potato (cv. H-268 and Pusa Safed) were established simultaneously with the component crops in 1 : 1 alternate ratio of rows 60 cm apart. Appreciable monetary advantages (Rs.10,441/- to Rs.14,730/-) were obtained from maize / sweet potato intercroppings, when sweet potato was relay planted. The valuation of the sole crop yields of soybean, maize, pigeonpea and sweet potato (high-yielding varieties) ranged from Rs.8,844/- to Rs.11,852/-, Rs.10,470/- to Rs.11,823/-, Rs.4,200/- to Rs.5,692/- and Rs.23,687/- to Rs.31,578/- per hectare, respectively in different years. Other spatial arrangements of soybean / sweet potato intercroppings were also remunerative (Rs.1,136/- to Rs.9,404/-) under simultaneous planting situation. Pigeonpea / sweet potato intercroppings, however, recorded monetary disadvantages.

Calorie value of the grain and tuber, produced per hectare of land, was highest in maize / sweet potato (ranging from 64.41 to

72.07 million cal / ha), followed by soybean / sweet potato intercroppings (47.04 to 61.93 million cal / ha), when sweet potato cv. H-268 or Pusa Safed was planted simultaneously with the component crops under 1 : 1 spatial arrangement (rows 60 cm apart). The calorie values of the grains or tubers of sole crops of soybean, maize, pigeonpea and sweet potato were 6.85 to 9.18, 14.53 to 16.18, 3.78 to 4.27 and 41.69 to 55.58 million cal / ha, respectively. Intercropping of maize with sweet potato, planted 45 days after maize was sown, also produced grains and tubers whose calorie values were more than that under sole sweet potato crop, planted at the time of sowing of grain crops.

Thus, it can be concluded that the long duration (200 days) crop of sweet potato, whose productivity in the light soils is very high, can profitably be grown in association with short duration varieties of soybean and maize in alternate rows (1 : 1) 60 cm apart, both crops established simultaneously. This showed not only increased productivity but also advantages in Land Equivalent Ratio, monetary return and calorific values of the produce. Appreciable advantages were also achieved from intercropping of maize with sweet potato in the same spatial arrangement, when sweet potato was interplanted 45 days later than the sowing of maize. The available physical resources were better utilised under the above mentioned intercroppings than under the sole croppings of sweet potato.

8. BIBLIOGRAPHY

Agboola, A.A. and Fayemi, A.A. (1972) Fixation and excretion of nitrogen by tropical legumes. Agron. J. 64 : 409-412.

*Ahlawat, R.P.S. and Samlal, R. (1979) A preliminary evaluation of crops under two farming systems at Coebiti. Proc. Caribbean Food Crops Soc. 15 : 98-106.

Ahmed, K. and Samad, M.A. (1976) Possible effects of planting date on the production of sweet potato. Bangladesh Hort. 4 (1) : 32-33.

Ahmed, S. and Gunasena, H.P.M. (1979) N utilization and economics of some intercropped system in tropical countries. Tropical Agric. 56 (2) : 115-123.

*Aidar, H. and Vieira, C. (1979) Intercropping of beans and maize. 3. Effect of plant population on dry season beans Revista Ceres 26 (147) : 465-473.

Aiyer, A.K.Y.N. (1949) Mixed cropping in India. Indian J. agric. Sci. 19 : 439-543.

*Akhanda, M.A.M. (1979) Evaluation of cultivars and cultural practices of several crops for tropical multiple cropping. Dissertation Abst. International B 39 (7) : 3082-3083.

Aykroyd, W.R. and Doughty, J. (1973) Legumes in human nutrition - FAO Nutritional Studies No. 19. F.A.O. Publication, Italy.

*Baker, E.F.I. and Norman, D.W. (1975) Cropping systems in Northern Nigeria. (In) Proc. Cropping Systems Workshop, I.R.R.I., Los Banos : 334-361.

Baldwin, J.P.; Tinker, P.B. and Nye, P.H. (1972) Uptake of solutes by multiple root systems from soil. II. The theoretical effects of rooting density and pattern on uptake of nutrients from soil. Plant and Soil 36 : 693-708.

Bhattacharyya, S. (1979) Intra species intercropping of rice. M.Sc. (Ag.) Thesis, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal. P. 73.

Bouwkamp, J.C. and Scott, L.E. (1980) Effect of plant density on yield and yield components of sweet potato. Annals Tropical Res. 2 (1) : 1-11.

Bowers, J.L.; Morelock, T.A.; Reed, M. and Vaughns, T. (1978) Effect of growing period length on sweet potato yields. Arkansas Farm Res. 27 (4) : 8.

*Centro International de Agricultura Tropical (1974) Multiple Cropping. (In) CIAT Annual Report for 1974 : 147-149.

Chan, L.M.; Johnson, R.R. and Brown, C.M. (1980) Relay intercropping soybeans into winter wheat and spring oats. Agron. J. 72 (1) ; 35-39.

*Chand, P. (1978) Studies on the effect of intercropping of maize with grain legumes and its impact on nitrogen economy and yield in Kulu Valley. Thesis Abst. 4 (3) : 178-179.

Chandra, S. (1978) Monoculture, mixed cropping and rotations : implications for Fiji agriculture, Fiji Agric. J. 40 (2) : 63-70.

*Chang, J.F. and Shibles, R.M. (1980) Competition studies on intercropped cowpea and maize. American Soc. of Agron., 72nd Annual Meeting, Madison, Wisconsin, U.S.A.

Chatterjee, B.N. and Mandal, N.C. (1975) Growth and yield of sweet potato (Ipomoea batatas (L) Lam.) in the gangetic plains of West Bengal. J. Root Crops. 1 : 25-28.

Chetty, C.K.R. and Rao, U.M.B. (1979) Experimental designs for intercropping systems and analysis of data. International Workshop on Intercropping, 10-13 Jan 1979. International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India.

Cochran, W.G. and Cox, G.M. (1967) Experimental Designs Modern Asia Edition, Charles E. Tuttle Co., Tokyo, 5th printing : P. 611.

*Cordero, A. (1978) Principles of intercropping; effects of nitrogen fertilization and row arrangement on growth, nitrogen accumulation and yield of corn and interplanted understory annuals. Dissertation Abst. International, B 39 (2) : 479-80.

Crookston, R.K. and Hill, D.S. (1979) Grain yields and land equivalent ratios from intercropping corn and soybean in Minnesota. Agron. J. 71 (1) : 41-44.

_____ and Kent, R. (1976) Intercropping - a new version of an old idea. Crops and Soils 28 (9) : 7-9.

Dalal, R.C. (1974) Effects of intercropping maize with pigeonpeas on grain yield and nutrient uptake. Exptl. Agric. 10 : 219-224.

*de Wit, C.T. (1960) On competition. Verslag Landbouwkundige Onderzoek 66 (8) : 1-81.

_____ and van den Bergh, J.P. (1965) Competition among herbage plants. Netherlands J. Agric. Sci. 13 : 212-221.

*Donald, C.M. (1946) Competition between pasture species with reference to the hypothesis of harmful root interactions. J. Council Sci. Industrial Res. 19 : 32-37.

_____ (1963) Competition among crop and pasture plants. Advn. Agron. 15 : 1-118.

*Finlay, R.C. (1974) Intercropping soybeans with cereals. Regional Soybean Conference (Proc.), Addis Ababa, 14-17th October.

Galal, S.; Hindi, L.; Abdalla, M.M.F. and Metwally, A.A. (1980) Soybean and corn yields under different intercropping patterns. (In) World Soybean Research Conference II. Abst. Corbin F.T. (Editor). Boulder, Colorado, Westview Press.

Gangwar, B. and Kalra, G.S. (1979) Studies on mixed cropping of legumes with maize under rainfed conditions. Madras Agric. J. 66 (7) : 425-429.

Giri, G. and De, R. (1978) Intercropping of pigeonpea with other grain legumes under semi-arid rainfed conditions. Indian J. agric. Sci. 48 (11) : 659-665.

Gollifer, D.F. (1980) A time of planting trial with sweet potatoes. Tropical Agric. 57 (4) : 363-367.

Hall, R.L. (1974a) Analysis of the nature of interference between plants of different species I. Concepts and extension of the de Wit analysis to examine effects. Australian J. Agric. Res. 25 : 739-747.

_____ (1974b) Analysis of the nature of interference between plants of different species II. Nutrients relations in a Nandi Setaria and Greenleaf Desmodium association with particular reference to potassium. Australian J. Agric. Res. 25 : 749-756.

Harper, J.L. (1961) Approaches to the study of plant competition. Symp. of the Soc. for Exptl. Biol. XV. Mechanisms in Biological Competition (Proc.) : 1-39

Haynes, P.H. (1970) Some general and regional problems of sweet potato (Ipomoea batatas (L.) Lam.) growing. Proc. 2nd Int. Symp. Trop. Root Tuber Crops, Hawaii 1 : 10-13.

Hegde, D.M. and Saraf, C.S. (1978) Light relations in pigeonpea as affected by intercropping and phosphorus fertilization. Indian J. Agron. 23 (4) : 379-80.

Hiebsch, C.K. and Mc Collum, R.E. (1980) Effect of remaining corn from corn-soybean intercrops on yield equivalency ratios. 72nd Annual Meeting. American Soc. of Agron. Madison, Wisconsin, USA.

Huxley, P.A. and Maingu, Z. (1978) Use of a systematic spacing design as an aid to the study of intercropping : Some general considerations. Exptl. Agric. 14 : 49-56.

Indian Agricultural Research Institute (1976) Beneficial effects from the introduction of legumes in crop rotations and intercropping systems. Reporter 1 (1) : 1-5.

International Crops Research Institute for the Semi-Arid Tropics (1976) Farming Systems (In) ICRISAT Annual Report 1975 - 76, Hyderabad, India : 149-209.

_____ (1977) Farming Systems (In) ICRISAT Annual Report 1976 - 77, Hyderabad, India : 129-197.

_____ (1978) Farming Systems (In) ICRISAT Annual Report 1977 - 78, Hyderabad, India : 165-230.

_____ (1980) Farming Systems (In) ICRISAT Annual Report 1979 - 80, Hyderabad, India : 165-230.

International Rice Research Institute (1974) Cropping systems (In) I.R.R.I. Annual Report 1974. Los Banos, Philippines 328-347.

_____ (1975) Cropping Systems Program Report 1975. Los Banos, Philippines N.73.

Jagannathan, N.T.; Morachan, Y.B. and Ramiah, S. (1979) Studies on the effect of maize and soybean association in different proportions on yield and grain. Madras Agric. J. 66 (11) : 719-721.

Jain, T.C. and Rao, G.N. (1980) Note on a new approach to analysis of yield data in intercropping system. Indian J. agric. Sci. 50 (12) : 970-972.

Jodha, N.S. (1976) Resource base as a determinant of cropping pattern. (In) Symposium on cropping systems research and development for the Asian rice farmer. International Rice Research Institute Loss Banos, Philippines, 21-23rd September.

Kalra, G.S. and Gangwar, B. (1980) Economics of intercropping of different legumes with maize at different levels of nitrogen under rainfed conditions. Indian J. Agron. 25 (2) : 181-185.

Kamalam, P.; Diradar, R.S. and Hrishi, N. (1978) Stability parameters in sweet potato (Ipomoea batatas (L.) Lam.) J. Root Crops 4(1) : 35-39.

*Kassam, A.H. (1972) Effects of plant population and interspecific competition on yield of sorghum and groundnuts under mixed cropping. Institute for Agricultural Research Reports, 1969 - 72. Samaru, Nigeria.

*_____ (1973) In search for greater yields with mixed cropping in Northern Nigeria - a report on agronomic work. Institute for Agricultural Research, Samaru, Nigeria.

Khera, A.S.; Brar, H.S. and Sharma, R.K. (1979) Studies on intercropping of maize (Zea mays L.) with blackgram (Phaseolus mungo Roxb.). Indian J. Agric. Res. 13 (1) : 23-26.

*Krantz, B.A.; Virmani, S.M.; Sardar Singh and Rao, M.R. (1976) Intercropping for increased and more stable agricultural production in the semi-arid tropics. (In) Symposium on Intercropping in Semi-Arid Areas (Proc.). Morogoro, Tanzania, 10-12th May.

Kundu, A.L. and Chatterjee, B.N. (1982) Growth analysis of turmeric as a sole crop and in mixture with other crops. Indian J. agric. Sci. 52 (7) :

*Lakhani, D.A. (1976) A crop physiological study of mixtures of sunflower and fodder radish. Ph.D. Thesis Reading Univ. England.

*Lin, S.H.; Han, X.-L.; Zhao, M.-Z. and Kong, Y.-Z. (1981) (Studies on solar energy utilization, crop competition and yield analysis in doublecropped wheat fields on the north China plain.) Acta Agronomica Sinica 7 (1) : 63-72.

Litsinger, J.A. and Moody, K. (1975) Integrated pest management in multiple cropping systems. (In) Multiple cropping Symposium (Proc.). American Soc. of Agron. Annual Meeting, Knoxville, Tennessee, 24-29th August.

Mc Gilchrist, C.A. (1965) Analysis of competition experiments. Biometrics 21 : 975-985.

Mead, R. and Willey, R.W. (1980) The concept of a 'land equivalent ratio' and advantages in yields from intercropping. Exptl. Agric. 16 (3) 217-228.

Mohta, N.K. and De, R. (1980) Intercropping maize and sorghum with soybeans. J. Agric. Sci. UK 95 (1) : 117-122.

Nair, K.P.P.; Patel, U.K.; Singh, R.P. and Kaushik, M.K. (1979) Evaluation of legume intercropping in conservation of fertilizer nitrogen in maize culture. J. Agric. Sci. UK 93 (1) : 189-194.

Natarajan, M. and Willey, R.W. (1980) Sorghum-pigeonpea intercropping and the effects of plant population density. I. Growth and yield. II. Resource use. J. Agric. Sci. UK 95 (1) : 51-58; 59-65.

Nelliat, E.V.; Bavappa, K.V. and Nair, P.K.R. (1974) Multistoried cropping. A new dimension in multiple cropping for coconut plantations. World Crops Nov./Dec. : 262-266.

*Norman, D.W. (1972) An economic survey of three villages in Zaria Province. II. Input - output relationships. Ahmadu Bello University, Samaru, Nigeria.

*Osiru, D.S.O. (1974) Physiological studies of some annual crop mixtures. Ph.D. Thesis, Makerere University, Kampala, Uganda.

Panse, V.G. and Sukhatme, P.V. (1967) Statistical Methods for Agricultural Workers. ICAR, New Delhi, India. P. 381.

Pinchinat, A.M.; Soria, J. and Bazna, R. (1975) Multiple cropping in tropical America (In) Multiple Cropping Symposium (Proc.), American Soc. of Agron., Annual Meeting, Knoxville, Tennessee, 24-29th August.

*Raheja, A.K. (1977) Pest and disease relationships within various crop mixtures. Research Program 1977 - 78. II. Cropping Systems. Institute for Agricultural Research, Samaru, Nigeria.

Raheja, P.C. (1953) Double cropping. Review series of Indian Council of Agricultural Research 8 : 7-8.

_____ (1971) Mixed cropping. Rakesh Press, Aziz Ganj, Delhi.

_____ (1973) Mixed cropping. Indian Council of Agricultural Research Technical Bulletin No.42 New Delhi, India.

*Rai, M.; Varma, S.P.; Ghosh, A.K. and Dhandar, D.G. (1982) Optimum planting time and high yielding sweet potato variety for uplands of Tripura : 126-127. ICAR Res. Complex for N.E.H. Region, Lembachera, Tripura, India. Field Crop Abst. 35 (1) : 91.

Rao, M.R. and Shetty, S.V.R. (1977) Some biological aspects of intercropping systems on crop-weed balance. (In) Weed Science Conference/Workshop in India (Proc.). Andhra Pradesh Agricultural University, Hyderabad, India 17-20th January.

_____ and Willey, R.W. (1980) Evaluation of yield stability in intercropping : studies on sorghum / pigeonpea. Exptl. Agric. 16 (2) : 105-116.

Rathke, J.K. and Hegstrom, R.T. (1975) Strip intercropping for wind protection. (In) Multiple Cropping Symp. (Proc.). American Soc. of Agron. Annual Meeting, Knoxville, Tennessee, 24-29th August.

Rathore, S.S.; Chauhan, G.S. and Singh, H.G. (1980) Stand geometry of maize and its intercropping with pulses under dry land agriculture. Indian J. Agron. 25 (3) : 319-322.

Reddy, M.N. and Chatterjee, B.N. (1973a) Nodulation in soybean grown as a pure and mixed crop. Indian J. Agron. 18 (4) : 410-415.

_____ and _____ (1973b) Intercropping of soybean with rice. Indian J. Agron. 18 (4) : 461-472.

_____ and _____ (1974) Mixed cropping of soybean with rice, maize and sorghum gives more yield than pure crops. Agric. and Agro-Industries J. April, 1974.

Reddy, M.N. and Chatterjee, B.N. (1976a) Mixed cropping of soybean with maize. Indian J. Agron. 20 (4) : 341-345.

_____ and _____ (1976b) Undersowing of soybean into rice and rice into soybean at later stages of their development. J. Soc. Exptl. Agric. 1 (2) : 39-42.

Rice, E.L. (1974) Allelopathy, Academic Press, New York.

Saxena, M.C. and Yadav, D.S. (1979) Parallel cropping with short-duration pigeonpea under the humid sub tropical conditions at Pantnagar. Indian J. agric. Sci. 49 (2) : 95-99.

_____ ; _____ ; Singh, H.P. and Paliwal, V.C. (1977) Studies on parallel cropping in pigeonpea under humid sub tropical conditions of Nainitaltarai. Legume Res. 1 (1) : 27-32.

Searle, P.G.E.; Comudom, Y.; Shedden, D.C. and Nance, R.A. (1981) Effect of maize + legume intercropping systems and fertilizer nitrogen on crop yields and residual nitrogen. Field Crops Res. 4 (2) : 133-145.

Shanmugavelu, K.G.; Thamburj, S.; Shanmugam, A. and Gopalaswamy, N. (1972) Effect of time of planting and type of planting material on the yield of sweet potato. South Indian Hort. 20 (1) : 55-58.

Siddoway, F.H. and Bonnett, A.P. (1975) Water and wind erosion control aspects of multiple cropping. (In) Multiple Cropping Symposium (Proc.), American Soc. of Agron. Annual Meeting, Knoxville, Tennessee, 24-29th August.

Singh, C.M. and Chand, P. (1980) Note on economics of grain legume intercropping and N fertilization in maize. Indian J. agric. Res. 14 (1) : 62-64.

_____ and Guleria, W.S. (1979) Effect of intercropping and fertility levels on growth, department and yield of maize (*Zea mays* L.). Food Fmg. Agric. 10 (7): 242-244.

Singh, M.; Singh, K.; Singh, R.K. and Saumitra, B.S. (1979) Effect of intercrops on the growth and yield of pigeonpea. Indian J. agric. Sci. 49 (2) : 100-104.

Singh, S. and Balasubramanian, A. (1979) Research Accomplishments. A. Crop Improvement. 50 Years of Agricultural Research and Education, Indian Council of Agricultural Research.

*Singh, S.P. (1977) Intercropping and double-cropping studies in grain sorghum. (In) International Sorghum Workshop, ICRISAT, Hyderabad, India. 6-12th March.

Sivakumar, M.V.K. and Virmani, S.M. (1980) Growth and resource use of maize / pigeonpea intercrop in an operational research watershed. Exptl. Agric. 16 (4) : 377-386.

*Syariffuddin, A.; Effendy, S.; Ismail, I.G. and Mc Intosh, J.L. (1974) Performance of corn peanut, mungbean and soybean in monoculture and intercrop combinations of corn and legumes in dry season 1973. Rep. No. 12 Cent. Res. Inst. Agric. Bogor, Indonesia.

*Thompson, D.R. (1977) The effect of cereal height on performance of stands intercropped with soybeans. M.Sc. Thesis. University of Dar es Salam, Morogoro, Tanzania.

Toib, M.A. and Rashid, M.M. (1976) Effect of time of planting and harvesting on the yield of sweet potato. Bangladesh Hort. 4 (1) : 1-6.

Trenbath, B.R. (1974) Biomas productivity of mixtures, Advn. Agron. 26 : 177-210.

*Umrani, N.K. and Pharande, K.S. (1979) J. Marathwada Agriculture University 4 (3) : 311.

Wang, H. (1975) The breeding and cultivation of sweet potatoes. Food and Fert. Tech. Centre. Tech. Bull. No. 26 : 41.

Watarabe, K. (1979) Agronomic studies on the mechanism of excessive vegetative growth in sweet potato (Ipomoea batatas (L.) Lam.) J. Central Agric. Expt. Stn. No. 29 : 1-94.

*Wien, H.C. and Nangju, D. (1976) The cowpea as an intercrop under cereals. (In) Symposium on Intercropping in Semi-Arid Areas (Proc.), Morogoro, Tanzania, 10-12th May.

Willey, R.W. (1979) Intercropping - its importance and research needs. Part I. Competition and yield advantages. Part II. Agronomy and Research Approaches. Field Crop Abst. 32 : 1-10; 73-85.

_____ and Osiru, D.S.O. (1972) Studies on mixtures of maize and beans (Phaseolus vulgaris) with particular reference to plant population. J. Agric. Sci. UK 79 : 519-529.

_____ and Rao, M.R. (1980) A competitive ratio for quantifying competition between intercrops. Exptl. Agric. 16 (2) : 117-125.

Yadav, R.L. (1981) Intercropping pigeonpea to conserve fertilizer nitrogen in maize and produce residual effects on sugarcane. Exptl. Agric. 17 (3) : 311-315.

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* Original not seen

APPENDICES

APPENDIX - II

Cost of production

Particulars	Soybean (S) in Rs.	Maize(M) in Rs.	Pigeon -pea in Rs.	Sweet potato (SP) in Rs.	S/SP 1 : 1 (rows at 60 cm) in Rs.	M/SP 1 : 1 (rows at 60 cm) in Rs.
1. Land preparation and layout	510/-	430/-	290/-	290/-	500/-	430/-
2. Fertilizers and application	531/-	723/-	531/-	723/-	635/-	723/-
3. Seeds and sowing/ planting	570/-	162/-	148/-	610/-	840/-	756/-
4. Plant protection including watching	397/-	815/-	481/-	443/-	609/-	1043/-
5. Interculture	368/-	528/-	288/-	896/-	936/-	896/-
6. Irrigation				522/-	522/-	522/-
7. Harvesting and processing	714/-	954/-	744/-	1204/-	1278/-	1838/-
8. Miscellaneous (rent on land, repairing and depreciation and interest on capital	452/-	504/-	424/-	755/-	818/-	907/-
Total expenditure	3,542/-	4,116/-	2,906/-	5,443/-	6,138/-	7,115/-

Ploughing and planking @ Rs.70/- per hectare per time; Labour day @ Rs.8/-; Cart @ Rs.10/-; Urea, Single super phosphate and Muriate of potash @ Rs.160/-, 60/- and 90/- per quintal, respectively; Watching @ Rs.200/- per month; Irrigation (water charge and labour) @ Rs.174/- per time