CROP GEOMETRY STUDIES IN SUNFLOWER IN ASSOCIATION WITH GROUNDNUT

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C E R T I F I C A T E

Sri SHAIK MOHAMMAD has satisfactorily prosecuted the course of research and that the thesis entitled **"CROP GEOMETRY STUDIES IN SUNFLOWER IN ASSOCIATION WITH GROUNDNUT"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

Date: 29- 8-1986

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C E R T I F I C A T E

This is to certify that the thesis entitled, **"CROP GEOMETRY STUDIES IN SUNFLOWER IN ASSOCIATION WITH GROUNDNUT"** submitted in partial fulfilment of the requirements for the degree of **"DOCTOR OF PHILOSOPHY** of the ANDHRA PRADESH AGRICULTURAL UNIVERSITY, HYDERABAD, is a record of the bonafide research work carried out by **Sri SHAIK MOHAMMAD** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma or has been published. Published part has been fully acknowledged. All the assistance and help received during the course of investigations have been duly acknowledged by him.

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LIST OF ABBREVIATIONS

S	Sole crop
I	Intercrop
N	Narrow rows
W	Wide rows
E	Equidistant row arrangement
P	Paired row arrangement
SN	Sole narrow
SW	Sole wide
SE	Sole equidistant
SP	Sole paired
NE	Narrow equidistant
NP	Narrow paired
WE	Wide equidistant
WP	Wide paired
SSN	Sole sunflower narrow
SSW	Sole sunflower wide
GSN	Groundnut sole narrow
GSW	'Groundnut role wide
S x M	System x Method
S x P	System x Pattern
M x P	Method x Pattern
S x M x P	System x Method x Pattern
LER	Land equivalent ratio
PLER	Partial land equivalent ratio
Ls	Partial land equivalent ratio of sunflower
Lg	Partial land equivalent ratio of groundnut
SLER	Staple land equivalent ratio
RNR	Relative net returns

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ABSTRACT

Field experiments were conducted on the sandy loam soil at the students' Farm, Agricultural College, Rajendranagar in the summer seasons during 1983, 1984 and also during kharif 1983. One of the experiments was conducted with twelve treatments run over three replications in a 3×2^2 factorial randomised block design. This was intended to study the crop geometry of sunflower at a given density of 74×10^3 plants ha^{-1} in sole/intercrop system and to evaluate the possible benefits if any by intercropping with groundnut. Another experiment was conducted in a systematic fan design with six treatments in four replications to evaluate the optimum planting density of sunflower in sole/intercrop system for maximum productivity.

The experimental findings revealed that the planting geometry of sunflower is not a critical variable in sunflower both in sole and intercrop system with groundnut. The growth and yield attributes, per cent and uptake of N, P and K in different parts at various phenological stages of crop growth were all marginally affected when intercropped with groundnut particularly

in the *kharif* season. Consequently sunflower under competitive stress with groundnut yielded (1306.14 and 1277.04 kg ha^{-1}) as high as in the sole crop (1389.79 and 1465.89 kg ha^{-1}) with only a marginal reduction of 6 and 13% during summer 1983 and 1984 respectively. In the *kharif* season, seed yield was significantly reduced when intercropped (663.64 kg ha^{-1}) than in sole stand (940.55 kg ha^{-1}). Oil % in the achenes was not influenced in the three seasons. The oil yield per hectare of sunflower in sole (514.44 and 550.74 kg ha^{-1}) and intercrop system (489.97 and 475.18 kg ha^{-1}) did not differ significantly in the summer seasons. In *kharif*, the sole crop yielded significantly higher quantity of oil (363.88 kg ha^{-1}) than when intercropped (252.33 kg ha^{-1}) with groundnut.

The crop growth, yield and yield attributes, the concentration and uptake of nitrogen, phosphorus and potassium by the leaves, stem or pods per plant of groundnut were severely affected when it was grown as an intercrop component. Production of pods in intercrop system was thus significantly depressed (855.76 and 1422.98 kg ha^{-1}) with only 43 and 60% of the sole crop yields (2018.93 and 2380.90 kg ha^{-1}) obtained during summer 1983 and 1984 respectively. In *kharif* the sole crop was damaged by the wireworms and yet the yield (633.75 kg ha^{-1}) was 15% more than in the intercrop system (540.77 kg ha^{-1}). The oil yield in intercrop component was significantly lowered (255.31, 422.73 and 131.24 kg ha^{-1}) compared to the sole crop (647.34, 739.68 and 161.45 kg ha^{-1}) in the three seasons during summer 1983, 1984 and *kharif* 1983. Similarly, the yield of haulms per hectare was also significantly less in the intercrop system. The yield of pods, haulms and oil per hectare were substantially increased by the equidistant row treatments than the paired row pattern. But, the narrow or wider row width treatments did not influence the performance of groundnut.

Intercropping increased the total oilseed production (2161.90, 2702.96 and 1204.42 kg ha^{-1}) by 55, 84 and 28% over the sole crop of sunflower (1389.79, 1465.89 and 940.55 kg ha^{-1}) and by 7, 13 and 90% over the sole crop yield of groundnut (2018.93, 2380.69 and 633.75 kg ha^{-1}) during summer 1983, 1984 and <u>kharif</u> 1983 respectively. The bivariate analysis indicated that the total oilseed production was significantly superior to the sole crop yield of sunflower in the summer seasons. Total oil yield due to intercropping (745.28 and 897.84 kg ha^{-1}) improved significantly in the summer seasons while the little improvement (383.57 kg ha^{-1}) in the <u>kharif</u> season was not significantly different from the sole crop of sunflower (363.88 kg ha^{-1}). The land equivalent ratios (LERs) due to varying crop geometry ranged from 1.31 to 1.51 during summer 1983, from 1.26 to 1.79 during summer 1984 and from 1.52 to 1.73 during <u>kharif</u> 1983. The higher staple land equivalent ratios indicated that sunflower was the dominant component in intercrop system irrespective of the planting geometry. The gross monetary returns and the calorific equivalents were also substantially higher in the intercrop system. The net profits per hectare were however maximum from the sole crop of groundnut while the per rupee returns with a lesser expenditure on sunflower were statistically similar in the summer seasons. In the <u>kharif</u> season sole crop of sunflower was not only most profitable with maximum net returns per hectare but also accrued the maximum per rupee returns.

The yield-density relationship of sunflower or groundnut was described by the power function $Y = ab^x$. Sunflower showed a plastic response to variation in planting density ranging from about 75 x 10^3 to 162 x 10^3 plants ha^{-1} with a corresponding row width of 27.5 to 60 cm at a constant intra-row spacing of 22.5 cm. Groundnut suffered severe pod/oil yield reduction while sunflower was little affected in the intercrop system althrough the range of planting densities varying from about 23 x 10^3 to 162 x 10^3 plants ha^{-1}. The total oilseeds/oil yield per hectare increased substantially and surpassed the sole crop yield of sunflower at any level of planting density when groundnut was intercropped over 3/4 of its shared area. The total oilseed production was maximised with an estimated optimum density of 88830, 107959 and 120140 plants ha^{-1} of sunflower intercropped over 3/4 of its area with groundnut.

CHAPTER I

INTRODUCTION

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INTRODUCTION

The global per capita consumption of fats and oils is increasing with the burgeoning world population. This requires increased production of edible vegetable oils to keep pace with the growing demand. World statistics indicate that the production of groundnut which is the major source of oil has remained almost static since last decade (Carley, 1983). Even in India though groundnut is the mainstay for internal and external economy of the country, it could not make a much headway in the recent past and the annual production of vegetable oils is far behind the local requirement. The scope for increasing the production of other traditional oilseed crops is also limited (Sen, 1979). The Government of India has imported 1.368 tonnes of edible oil at a cost of 11221.3 million rupees during 1984-85 to meet the domestic demand (ICAR Report, 1985). The acute shortage of oils in India and the worldover is thus alarming.

In an endeavour to exploit newer sources of oil with low production technology and higher oil output, sunflower traditionally known as an aesthetic garden plant has suddenly shot up into prominence on the agricultural scenerio. It could find a suitable niche in several parts of the world including an oil hungry country like ours. Presently it is being grown in significant commercial quantities in atleast twenty different countries and is the second most important source of vegetable oil in the world being next only to soybean (Jones, 1984). Interest in sunflower as an oilseed crop in India aroused recently since 1969, with the availability of promising Russian cultivars. The performance of these new introductions was satisfactory in the beginning. But, soon the area under cultivation declined from 3.4 lakh hectares during 1972-73 to 0.61 lakh hectares during 1979-80. But, with the intensification of research and support price, the crop has recently experienced a marvellous expansion in area. It has now changed from a limited acreage crop to one covering 9.0 to 9.5 lakh hectares and in some areas it has replaced kharif groundnut, rabi cotton and other minor crops (AICORPO, 1985).

Being a new introduction, the crop husbandry of sunflower has not been adequately studied in the country. One of the most important management considerations is choosing a plant density that will maximise the seed and oil yield with minimum costs. The spatial arrangement or geometry of plants in a crop community is another aspect that needs to be explored for efficient utilization of resources with minimum competition. Spacing between the plants can be manipulated within or between the rows at a constant or different level of plant population to adjust competition between the plants. Of these, row width manipulation is of particular interest both in sole and intercrop system. In sole crop its significance lies in the fact that the spacings too close between the rows make the cultural operations to be performed difficult and yield low due to overcrowding of plants. While, rows distant apart may not yield high owing to a shortfall in population beyond the required optimum. In intercrop system, the point of interest regarding the effect of row widths is the manipulation of the base crop to facilitate the accomodation of an intercrop. It is therefore necessary that the range of optimum row width for a crop species be worked out that would not impair the productivity. The response of intercrops to plant population and spatial arrangement are also just as important and deserving of the same detailed study as those of sole crops.

Intercropping is another way of increasing the oilseed production not by means of extra inputs but by the simple expedient of growing the crops together. Interest in this area of research has been spurred recently to understand the biological validity of the system by way of the possible increase in yield, more efficient use of prime land and perhaps the economic benefits of higher returns. Singh and Singh (1985) described that most of the earlier experiments were concerned largely with the advantages of traditional situations that were "survival oriented" rather than "production oriented". But, the main objective in the present day intercropping technology is to examine the benefits of the system when the production inputs under the level of management are high (Andrews, 1972; Willey and Osiru, 1972; Salter *et al*., 1985 and Singh and Singh, 1985).

It is therefore, interesting to explore the possibilities of intercropping sunflower with other crops without appreciable reduction in yield. As it is a widely spaced crop and has an inherent nature of plastic response to a change in row spaces as well as to a range of plant populations, it provides an opportunity for search of a companion crop with apparent advantages of increased productivity and/or economics. Since the growth habit indicates that it is an aggressive crop, it is easier to develop an intercropping system with sunflower as the base crop than as an intercrop. Groundnut being of a diverse morphology, growth habit and of comparatively longer duration can successfully be introduced as an intercrop component to make use of the potential interspace between the rows of sunflower. Being a legume, it had also been an important component of several intercrop systems and it may help in overcoming the ecological constraints due to the unique property of nitrogen fixation (Francis *et al*., 1976).

Evaluation of intercropping system in sunflower has been much less studied todate. Also, the information on intercropping of other oilseed crops in sunflower is scanty. The present experiments were therefore conducted in the summer seasons of 1983 and 1984 under irrigated conditions and in the *kharif* season of 1983 as a rainfed trial with the following objectives,

1. To evaluate a suitable planting pattern and row width of sunflower for groundnut intercropping.

2. To study the effect of intercropping on growth, nutrient uptake and yield of individual crop components compared to the sole crops under varying plant geometry.

3. To study the possibilities of maximising the total seed/oil yield by intercropping.

4. To assess the relative monetary advantage and land use efficiency of different intercrop treatments and

5. To assess the relative advantages or otherwise of intercropping compared to the sole crops over a wide range of plant densities as regulated by a systematic change in the row width of sunflower.

CHAPTER II

REVIEW OF LITERATURE

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The establishment of optimum plant population and geometry of plants in a crop community over a given land area are the most important determinants of crop yield. Plant population defines the number of plants per unit area which determines the size of the area available to the individual plant (Willey, 1979) and considering the yield *per se* the optimum population is the minimum population that produces maximum yield (Robinson *et al*., 1982). While, the spatial arrangement or the stand geometry defines the pattern of distribution of plants over the ground, which determines the shape of area available to the individual plant (Willey, 1979).

Population research is often confounded with the spatial arrangement of plants since a change in the population distribution can be effectively achieved by a change in the row spacing or distance between the plants within the rows. Nevertheless, crop geometry studies at a constant plant population have also been discussed although in a very few research publications. The reported findings on the response of sunflower and groundnut to variation in population density as well as crop geometry have therefore been reviewed separately for different situations following the review on the general growth pattern of each crop. Finally, aspects of groundnut intercropping in sunflower has been reviewed for biological and economic considerations. Literature on the experimental designs with particular reference to the development of systematic fan designs for plant population research, their merits and limitations thereof and an outline of the statistical procedure to be adopted has been provided preceding the review of work on sunflower and groundnut.

2.1 EXPERIMENTAL DESIGNS

In conventional experimental designs the treatments under study are normally allocated in plots which are usually distributed side by side in the field. This practice may give place to a tendency of positive correlation between neighbouring plots, which can disturb the theoretical basis of the method of the analysis of variance, particularly a misleading estimate of the error and test of significance. To solve this difficulty Fisher introduced the principle of randomization into experimental designs thus removing the problem of positive correlation of neighbouring plots. Therefore, yields can be examined as if their errors were incorrelated (Yates, 1938).

In his studies of plant population in sole cropping, Nelder (1962) pointed out "where spacing experiments are concerned, however, randomization may have disadvantages". Citing an instance he explained that if the spacing is being maintained in a square pattern for all densities then one may either keep a constant number of plants per plot, in which case the plots are all of different sizes and awkward to fit together in a block, or keep all plots of same size, in which case the close spacings may have an unnecessarily large number of plants in them. In addition, efforts to keep the block size small will lead to a large proportion of the plants in the experiment being used as guards. Where plant material or land is valuable this is unsatisfactory.

Working at Wellesbourne in England, with Brussels sprouts and cabbage, Nelder (1962) suggested that "correlations between neighbouring plots in field experiments may often be of little importance." This observation arose from an examination of split-plot experiments where it was concluded that mean square for blocks, main-plot error and sub-plot error were very similar and also from the observation that the standard error per plant for a particular crop remained fairly constant between experiments, showing that the major source of error lies more with plant variation than with soil variation. Based on these observations and considering that the studies of the effects on yield of a number of plant populations each one grown with different row arrangements, would require a considerable amount of land area, Nelder (1962) and Bleasdale (1967) developed the idea of the systematic designs which originally consisted of a gradual or systematic change of the plant densities along the 'block' and guard rows were placed only at the end of the block. This design was called a 'fan' design because of the similarity of its shape with a fan. It is formed of a grid of points, where each point indicates the position of a plant and having the property that the area per plant and/or the rectangularity (ratio of inter and intra-row distance) of each plant change in a systematic way over the different parts of the grid. It was indicated that an important condition imposed by the systematic fan designs is that the sets of curves are displayed as arcs of concentric circles and the density and rectangularity contours should not coincide, otherwise it becomes difficult to separate those effects.

The main advantage of the systematic fan design is undoubtedly the exclusion of guard rows between treatments, making possible the use of a large range of treatments on a relatively small area. This is particularly useful in exploratory studies when little is known about the crops. Apart from these advantages the systematic fan designs present the inconvenience of not permitting the intercultivation due to the concentric arrangement of the arcs.

A number of workers have used the systematic designs for spacing experiments. Freeman (1964) adopted the fan design for a systematic study on spacings with lettuce, Nichols (1967) with onions, Vijayalakshmi et al. (1975) with sunflower, Rao et al. (1976a) with sorghum and Sheldrake and Saxena (1979) with chickpea. These designs were also used in systematically arranged fertilizer experiments by Cleaves et al. (1970) with Brussels sprout, lettuce, carrots and redbeet.

Of the systematic designs so far used in intercropping, Huxley and Maingu (1978) and Wahua and Miller (1978) have used modifications of Nelder's (1962) fan design for combinations of maize/cowpea and sorghum/soybean respectively. The idea of the fan is that the spatial arrangement remains constant for all individual plants apart from changing density which varies consistently along each radius. Wahua and Miller (1978) used different segments of the fan for sole crops and intercrops. Huxley and Maingu (1978) reported that the assessment of the relative advantages or otherwise of intercropping compared with sole cropping needs to be done over a wide range of plant populations. Systematic spacing designs lend themselves to this. The systematic spacing experiments conducted at the start of any series of intercropping investigations into particular crop combinations could offer substantial clues as to the most likely optimal combinations from among the otherwise extremely large number of choices available of particular levels of all the different variables. This could lead to considerable economy of effort in laying down larger substantiating experiments of a conventional type.

Mead and Stern (1980) considered that the systematic designs have an important place in intercropping research and it is also important to realise that they raise new problems which must be considered in the context of the complete experiment. Typically systematic variation of a spatial factor will be only one component of an experiment which also includes other treatment factors (nutrients, genotypes) applied to whole systematic plots. The experiment thus resembles a split-plot design with spatial treatments as systematic split-plot treatments and the other treatments randomized and replicated as the main plots in the usual way.

Regarding the analysis of systematic designs we must obviously recognize that the data have different properties than for randomized designs. The conventional analysis of variance for split-plot designs is inappropriate for examining the differences between yields for different spacings because of the lack of randomization and also because the null hypothesis of no yield variation over different spacings is usually of no interest since it is clearly untrue. In cases where the dominant source of error variation is plant variability an ordinary split-plot analysis of variance may have some value as a preliminary indicator of patterns of variation. The use of a wide range of densities or spatial arrangements implies an interest in the response of yield to quantitative spacing factors and the analysis of data from a systematic design should usually start by examining the relationship of yield to density (or other spatial factor). This should first be done graphically, followed by fitting a response function of yield on the factor that varies in each systematic plot. Subsequent analysis will involve comparison of the response curves for the different main plot treatments in what is essentially an analysis of variation of response curves. The replications of the other factors provides information on the consistency of the response curves for a particular main plot treatment in the same way that replication in a standard design provides the errors of treatment means.

2.2 SUNFLOWER

2.2.1 General pattern of crop growth and phytomass accumulation

An understanding of the crop growth pattern and its development is of vital importance for the improvement and development of more appropriate cropping strategies. Therefore, a brief account of this is reviewed preceding the reports on plant population and crop geometry studies.

The growth of sunflower as measured by its height generally follows the typical sigmoid growth characteristic curve. The most rapid growth occurs between the period from late vegetative phase to flowering followed by a near cessation after seed setting (Rao, 1974 and English *et al.*,1979).

Though not an yield component plant height has a strong effect on the total possible leaves that the plants tend to form in putting on a large number (Green, 1980). Studies in Ghana revealed that the yield is positively correlated with plant height (Amable, 1980). Leaves increase in number with crop age upto seed setting and subsequently there would be no more addition (Rao, 1974). The active number of leaves per plant has a strong and an indirect effect on the yield of sunflower (Green, 1980). Iliev and Ilieva (1980) reported that the development of leaf area in sunflower is very intensive during the bud formation stage reaching the maximum values at flowering. However, Hocking and Steer (1983 a) reported that the maximum number of green leaves was attained at flower bud visible stage but maximum leaf area was not reached until three row anthesis. The area of green leaves remained constant during flowering and declined rapidly during seed filling.

The phytomass accumulation per plant increase till physiological maturity of the crop. The increase was reported to be slow in the initial stages during vegetative phase followed by a linear rise till bud formation. A considerable amount of phytomass was then reported to have been accumulated by seed setting stage of the crop (Rao, 1974). While, Hocking and Steer (1983 a) and Steer and Hocking (1984) reported that the period of maximum pytomass accumulation in sunflower coincides with the period between floret initiation and anthesis. Leaves increase in dry weight till flowering and drop-off towards harvest.

From experiments conducted at Rajendranagar, the accumulation of phytomass in stem was shown to continue till maturity (Rao, 1974). While, the observation recorded in New South Wales revealed that the maximum dry weight was attained at flowering which coincided with the maximum plant height (English et al., 1979). However, observations from both these trials indicated that initially the increase in dry weight of head was slow but linear from flower opening till seed filling stage of the crop after which the rate of increase declined till physiological maturity.

The findings from the above review indicate that the plant growth is very slow during the early vegetative phase, but is most intense from flower bud formation till flowering and seed setting stage. The peak physiological activity of the vegetative organs is thus centred around the flowering stage and decline towards maturity. The reproductive sink on the other hand draw the photosynthates from the vegetative parts and continue to develop till physiological maturity.

2.2.2 Response of sunflower to plant population

Sunflower plant population as a technological element that regulates the equilibrium between environment and genetic characters has been widely investigated in several parts of the world. The relationship "Plant population production" proved to be a very complex functional character relying upon a multitude of genetic, soil, climatic and cultural factors. As such the diversity of reports on the response of sunflower to low and conversely higher population as well as its ability to adjust over a wide range are reviewed.

2.2.2.1 Effect on yield and yield components

Disagreement as to optimum plant population is of common occurence within a region as well as among countries of the world and differences within a region are as great as those between different countries (Akhanda et al., 1979). Population of 40,000 to 50,000 plants per hectare were recommended for rainfed and 50,000 to 60,000 plants per hectare for irrigated fields in Romania (Albinet et al., 1968). Reviewing the work done in different countries, Jensma (1973) reported that the optimum number of plants per hectare would be 45,000 for the dry soils in Spain and on irrigated land this could be increased to 60,000. The Italian trials indicated an optimum density of 40,000 to 80,000 plants per hectare for the tall and short varieties respectively. He suggested that about 60,000 to 1,00,000 plants per hectare would be optimum as far as India is concerned. But, from the review of research in Tamil Nadu, Varisai Muhammed and Subramanian (1973) concluded that a population of 50,000 plants per hectare is optimum for sunflower. Populations of 57,000 to 64,000 plants per hectare were recommended for southern Manitoba (Enns and Giesbrecht, 1971 ; 50,000 plants per hectare for Argentina (Luciano and Davreux, 1967); 43,000 to 54,000 for Bangla Desh and Pakistan (Mian and Gaffer, 1971 and Khan Muhammad, 1974); 28,500 to 40,500 for non-oilseed and 42,000 to 45,000 plants per hectare for oilseed sunflower in China (Deshen, 1982).

From several experiments conducted over different locations in North Dakota, Zubriski and Zimmerman (1974) recorded a positive response of sunflower to an increase in density from 35,875 to 71,750 and from 28,700 to 47,835 plants per hectare for the oilseed and confectionery type of sunflowers. The requirement of a higher density increasing from 30,000 to 60,000 plants per hectare for higher yields was also noticed in field experiments at Bangalore (Shanthamallaiah, et al.,1977).

Akhanda et al. (1979) reported that the seed yield of three sunflower cultivars tested in Florida increased with density and was maximum with 80,000 plants per hectare. However, in the subsequent year (Smith et al.,1981) it was observed that though the yield was highest with a population of 80,000 plants per hectare, it was not significantly different from the additional density tested with 1,20,000 plants or a lower density of 40,000 plants per hectare. Smith et al.(1983) further observed that the seed yield per plant, thousand seed weight and the capitulum diameter decreased at higher planting density.

Reddy and Rao (1984) also recorded an increase in the yield of sunflower cultivar - 'Peredovik' as the density was raised from 55,555 to 1,11,111 plants per hectare at Rajendranagar. A similar response was attained with the short duration dwarf cultivar - 'Morden', a year later at this location (Rao et al., 1985).

Though response to higher planting densities has been documented, better performance even with lower plant population has also been reported in literature. From field experiments in Western North Dakota, Alessi et al.(1977) obtained maximum yields with 25,000 than with 50,000 plants per hectare. Vijayalakshmi et al. (1975) also reported that the field experiments conducted at Saskatchewan, Canada, recorded higher yields with low population of 25,000 plants per hectare, while there was a decline at higher densities of 75,000 and 1,25,000 plants per hectare. However, the mid-density was not significantly different from the lower and higher populations. This contradicts the results obtained by the authors at Hyderabad where the response was attained at a higher range of densities (56,000 to 98,000 plants per hectare). In Yugoslavia, Stanojevic and Mihaljcevic (1982) observed that the seed yield of rain-grown sunflower was significantly increased with a planting density of 47,000 plants per hectare than those with 36, 57 or 67 thousand plants per hectare. Kumar, et al. (1985) reported that a planting density of 37,000 or 55,555 plants per hectare at Bangalore consistently recorded higher yields than 74,000 plants per hectare during the kharif, rabi and summer seasons.

In contrast to the yield response at high or low densities, the available literature also indicates the compensatory response of sunflower crop to a range of plant populations. The crop has been shown to adjust to low population by increasing the capitulum diameter, number of seeds per head and the yield per plant and to high populations by decreasing them. Robinson et al. (1982) reported that sunflower at populations of 25 to 150% in excess of the optimum did not suffer reductions in yield. Miller and Roath (1982) further observed that the yield compensation over a range of densities occurs when the plant population is reduced even after the crop establishment. In an experiment at North Dakota, they recorded no significant reduction in yield with 25% of the plants from check (50,000 plants per hectare) removed at 4, 8 and 16 leaf growth stages.

Vijayalakshmi et al. (1975) reported that the seed yield of sunflower cultivar - 'EC 68415' tested under the dryland conditions at Hyderabad was practically constant at about 1350 kg ha^{-1} across a population range of 56,000 to 98,000 plants per hectare. A secondary yield plateau of about 900 kg ha^{-1} was found at populations of 18,000 to 32,000 plants per hectare. Yield similarity within each range resulted from an internal adjustment of yield components. Since populations ranging from 20,000 to 30,000 plants per hectare could produce 70% of the maximum yield, they suggested that these low populations could be an important factor in developing systems of intercropping. Swallers and Fick (1973) and Robinson et al. (1976) also reported that the plant population had little effect on yield of sunflower in Eastern North Dakota and the adjoining areas of Minnesota.

Field experiments conducted at the USDA, Southern Great Plains Research Centre at Bushland, Texas (Unger *et al.*, 1976) and those at North Dakota (Jones,1984)indicated that the seed yield of raingrown sunflower was not affected by a planting density of 25,000; 35,000 or 45,000 plants per hectare.

Miller and Fick (1978) compared the performance of three hybrid sunflowers with that of the major open-pollinated cultivar - 'Peredovik' at populations of 36,000; 48,000 and 72,000 plants per hectare at two sites in North Dakota and Minnesota. They observed that the three hybrids and Peredovik responded similarly to changes in plant population for each of the three year testings. Yield and test weight were not significantly altered by the three plant populations evaluated. As plant population increased head size and seed weight decreased.

Prunty (1981)studied the response of three sunflower cultivars grown under rainfed and irrigated conditions at two sites located in carrington and Fargo in North Dakota. Populations ranging from 49,000 to 69,000 and from 39,500 to 59,000 plants per hectare at the two locations did not influence the seed yield significantly. In a later study, it was further noticed that the plant populations of 49,700; 60,800; 74,600 and 92,200 plants per hectare did not influence the seed yield of any of the three hybrids tested even with different levels of moisture (Prunty, 1983). From the irrigated trials in Argentina, Hernandez and Orioli(1982) also reported that the crop sown with 56,000 or 1,66,000 plants per hectare recorded similar yields. In Australia Thompson (1982) demonstrated that the sunflower crop grown under irrigated conditions compensated for large differences in plant population ranging from 50,000 to 1,40,000 plants per hectare.

Yield compensation to a range of densities varying from 27,556 to 1,66,500 plants per hectare was also recorded in three out of five seasons study at Rajendranagar (Shaik Mohammad and Sagar 1983). A similar yield-density relationship was also established over a range of 40,000 to 85,000 plants per hectare at Saskatoon, Saskatchewan in the semi-arid prairies of Canada (Holt and Campbell, 1984) and from 28,700 to 73,200 plants per hectare at two locations in the humid growing conditions in North Central USA (Miller et al., 1984).

Research supporting the influence of environmental and genotypic factors on the yield response of sunflower to planting densities has also been published in literature. Robinson et al. (1980) considered that plant population is a major factor affecting the seed yield at different locations mainly due to variations in soil, temperature and rainfall. Minimum population for maximum yield was reported to vary from 25,000 to 62,000 plants per hectare among different locations in Minnesota. Optimum populations were 62,000 at Waseca and Grand rapids; 37,000 at Lamberton; 49,000 at Morris and Crookston and 25,000 at Becker. The response to both oil and non-oil types was similar at all locations. For South Queensland, George and Greenaway (1983) also suggested that the planting rate of sunflower should be varied according to the district, the soil moisture, planting time and the expected crop emergence. They recommended that a plant population of 30,000 to 50,000 plants per hectare for the rain-grown crop and under irrigation 70,000 to 1,00,000 plants per hectare should be used.

Vranceanu et al. (1982) evaluated the yield-density relationship of 24 sunflower hybrids across a population range of 20,000 to 70,000 plants per hectare at Fundulea in Romania. The optimum plant population for hybrids with plant height over 125 cm was reported to range between 55,000 to 60,000 plants per hectare. They observed that the seed yield curves for plants shorter than 125 cm were ascending at 70,000 plants per hectare reaching or even surpassing the maximum yields of medium or high stem hybrids.

The review on planting densities of sunflower indicate that though a plethora of literature is available there appears no common agreement as to the requirement of optimum plant population. Some research workers have emphasised the use of lower planting densities as low as 25,000 plants per hectare. While, others have obtained substantially higher yields with populations exceeding 1,00,000 plants per hectare. Nonetheless a large number of research reports have confirmed that the sunflower has a remarkable ability to adjust to a range of plant populations giving similar yields. In view of these divergent reports it is appropriate that the optimum density should be decided based on location specific trials under different management conditions.

2.2.2.2 Effect on oil per cent and oil yield per hectare

The per cent concentration of oil in the seeds and oil yield per hectare are of great concern to the growers. Hence a background of information on the performance of sunflower in relation to the per cent oil composition and oil yield due to variation in planting densities assues a significance of practical importance and helps in planning proper crop production practices.

Oil per cent in the seed is sometimes related to the planting density as observed by Robinson *et al*. (1980). They recorded a significant rise in oil per cent of sunflower consequent to a rise in density from 17,000 to 62,000 plants per hectare. Miller and Roath (1982) also observed that the oil per cent of sunflower seeds was reduced when the crop was grown at a lower planting density of 12,500 plants than with a population of 25,000 to 50,000 plants per hectare. Smith *et al*. (1983) similarly recorded an increase in the oil by 0.24% with an increase of every 10,000 plants from 40,000 to 80,000 plants per hectare. Holt and Campbell (1984) observed that though the increase in oil per cent was small, the improvement was statistically significant with density increasing from 40,000 to 80,000 plants per hectare.

In contrast to these reports, Alessi _et al_. (1977) obtained highest oil yield for the lowest population from a range of 25,000 to 1,00,000 plants per hectare. Reddy and Rao (1984) also observed that a lower density of 55,555 plants per hectare had a higher concentration of oil per cent than in seeds obtained with a population of 74,074 and 1,11,111 plants per hectare. Similarly, Kumar _et al_. (1985) reported that the oil per cent declined at higher densities of 55,000 and 74,000 plants per hectare than at a lower plant population of 37,000 plants per hectare irrespective of the growing season.

Most of the research findings have, however, clearly demonstrated that the planting density has little or no effect on the oil per cent and oil yield per hectare. Zubriski and Zimmerman (1974) reported that the populations established in the range of 35,875 to 71,750 plants per hectare over several locations in North Dakota for oilseed and confectionery type of sunflower indicated that the density _per se_ had no influence on the oil per cent.However, oil yield was reported to increase with density. Populations in the range of 25,000 to 45,000 plants per hectare in the Southern Great plains of Texas (Unger _et al_., 1976) and those ranging from 36,000 to 72,000 plants per hectare in North Dakota and Minnesota (Miller and Fick, 1978) also did not alter the oil per cent of different hybrids and test cultivars. Radford (1978) reported that an optimum population for higher oil yields in the clay soils of Queensland in Australia lies in the range of 50,000 to 1,00,000 plants per hectare. The best oil yields in rainfed sunflower would be in the range of 40,000 to 60,000 plants per hectare. Shaik Mohammad and Rama Rao (1981) observed that the oil per cent as well as the oil yield per hectare were not influenced by the plant population across a range of 27,556 to 1,66,500 plants per hectare. Similarly, trials conducted at Carrington and Fargo with three cultivars of sunflower indicated that the oil per cent was fairly constant across a range of 49,400 to 69,200 plants per hectare. But, a lower population of 39,500 plants per hectare experienced a significant depression. However, oil yield did not vary with densities ranging from lowest to the highest (Prunty, 1981). In another trial the author evaluated the response of three sunflower hybrids in the range of 49,700 to 91,100 plants per hectare under varying moisture regimes and found that the oil per cent was not influenced significantly (Prunty, 1983). Thompson (1982) reported that the sunflower crop established over a range of 50,000 to 1,40,000 plants per hectare under irrigated conditions in Australia yielded similar quantity of oil. Miller <u>et al</u>. (1984) also observed that the oil yield was not influenced by variation in planting density of sunflower from as low as 28,700 to as high as 73,200 plants per hectare.

2.2.3 Response of sunflower to crop geometry

The spatial arrangement of plants within the crop community is another component of population pressure and is distinct from but related to the overall density of the crop. It can be manipulated by changing the degree of rectangularity in order to adjust between plant competition within the monoculture crop community or to adjust a suitable companion crop for intercropping. This manipulation can be possible by a change in the row width or/and plant spacing at a constant or different level of population per hectare.

2.2.3.1 Effect of row width at constant plant spacing

Spacing between the rows depends upon the size of the plants at maximum vegetative growth, the extent they cover the soil, fertility status and availability of moisture in the soil as well as the cultural practices adopted. A point of interest on literature search relevant to the present studies is the manipulation of base crop to facilitate the accomodation of an intercrop.

From field studies conducted at Patna during the *rabi* season, Roy *et al*. (1977) observed that the pattern of response to row width of sunflower varies with the genotype. They reported that the cultivar 'Sunrise' performed better at a narrow row spacing of 30 cm while the yields were depressed at 45 or 60 cm. But, the cultivars - 'EC 68413' and 'EC 68414' did not yield significantly different at any of the three row spacings. However, the same cultivars tested at Sabour with similar treatments in the same season did not show the genotypic variation in response to row width variables. Rows spaced wider with 60 or 45 cm were reported to yield significantly higher quantity of seed than at 30 cm with a constant plant spacing of 20 cm in the three seasons (Singh et al., 1977).

Suraj Bhan (1977) reported that the plants under 60 cm row spacing in general showed bigger head size and higher 1000 grain weight, reduced plant height and delayed maturity of the crop as compared to 45 cm row spacing with a constant intra-row spacing of 25 cm. But, the grain yield was reported to be more with 45 cm and significant in one of the two year field trials conducted in the rabi seasons at Kanpur.

Chauhan (1979) reported that the culivar - 'Peredovik' responded better with significantly higher yields at a row spacing of 60 cm than at 45 or 30 cm grown at a constant plant spacing of 22.5 cm in the kharif season at Kanpur. Later Singhi and Pacheria (1981) also tested this variety with similar row and plant spacing treatments in the kharif season at Udaipur. It was found that the seed yield at 45 and 60 cm was on par and significantly superior to 30 cm. Plant growth was also reported to be better with wider row spacings. Plant height increased, while the stem girth and head diameter decreased with decrease in row spacing.

2.2.3.2 Effect of plant spacing at constant row width

Changes in the intra-row spacings have less effect on yields than changing the spacing between the rows. However, spacings less than the optimum may be injurious due to overcrowding of plants. Significant influence of plant spacing on seed yield and growth characteristics of sunflower were demonstrated in field studies at Georgia. Plants were spaced 15, 30 and 46 cm in rows 1.1 m apart. Seed yield per hectare was reported to decrease, while yield per head and head diameter increased with increase in plant spacing. But, spacing did not affect the plant height or the number of leaves per plant (Massey, 1971).

Srinivas and Patil (1977) also reported a better response of irrigated sunflower, yielding higher quantity of seed at closer spacing of 20 cm than the wider plant spacing of 30 or 40 cm in rows spaced 45 cm apart. Rate of phytomass accumulation and leaf area per plant were highest at the widest spacing whereas the leaf area index was highest at the closest spacing. But, studies in Iran (Karami, 1980) indicated an increasing trend in yield with wider spacing between plants at a row width of 60 cm. Plant spacings tested from 15 to 30 cm with increments of 5 cm indicated that the widest plant spacing recorded 9 per cent more yield than 15 cm. Plant height, head diameter and thousand seed weight increased with wider spacing between plants.

Remussi et al. (1974) working on the response of sunflower to plant spacing across a range of 5 to 50 cm in rows spaced 70 cm apart concluded that the plants closer than 20 cm were injured by the proximity of other plants. While, Hoes and Huang (1976) reported that with closer spacing, there would be increased chances of contact with sclerotia causing stem rot by the increased mass of roots,resulting in greater number of diseased plants.

Differential response of varieties to plant spacings at 60 cm row width was reported by Ramaswamy et al. (1974 a). In kharif season at Coimbatore, they observed that the cultivar - 'EC 68413' did not show a difference in yield due to different plant spacings. But 'EC 68415' recorded more yield with 30 and 22.5 cm than with 15 cm.

A number of other studies indicated that the plant spacing across a range is not a critical yield variable. Beard et al. (1976) reported that the effect of plant spacing appears to be less dramatic. Sunflower can compensate for differences in plant spacing and would give maximum yields with plant spacing of 20 to 40 cm and row spacing of 50 to 75 cm.

Shipley and Regier (1976) reported that the plant spacing of 10, 15 and 20 cm within 100 cm spaced rows did not affect the yield significantly. Similar response to different plant spacings was also confirmed by Ogunremi (1978 a) in South-West Nigeria. Six varieties were tested over six locations for three years with plant spacings of 22, 30, 38 and 46 cm in rows spaced 60 cm apart. Yield was not influenced by variations in intra-row spacings at all the locations. With 90 cm row spacing and plants spaced from 30 to 90 cm, Ogunremi (1978 b) observed that the yields increased with spacing upto 60 cm beyond which further increase in plant spacing depressed the yield.

Robles and Guajardo (1979) reported a greater flexibility of the crop to different spacings ranging from 20 to 35 cm in spring and from 25 to 35 cm in summer at a row spacing of 92 cm. However, at closer spacing of 10 and 15 cm yields were depressed. The results of Beard and Ingebretsen (1980) also indicated that the yields were depressed when plants were spaced 10 cm within the rows grown 76 cm apart, while compensation occured due to spacings of 20 to 40 cm.

Kcloczowski and Horodyski (1980) reported that the yield compensation occured for spacings varying from 22 to 35 cm between the plants at a row width of 60 cm in Poland. It was concluded that a spacing of 60 x 30 cm or a density of 55,000 plants per hectare is appropriate for maximum yields. Similarly in Cyprus, it was observed that the yield of sunflower hybrid 'HS-52' sown at a distance of 30, 40, 50 or 60 cm between the plants at a constant row width of 45 cm did not differ significantly (Hadjichristodoulu, 1984).

2.2.3.3 Effect of change in spacing within and between the rows

No consistent results have so far been reported for the different or same tract with regards to the spatial configuration of plants that would maximise the sunflower yields. For North Indian conditions Vikram Singh and Chunmun Singh (1972) recommended a spacing of 80 x 20 cm from several spacing combinations tried. In South, the experiments conducted with spacings ranging from 15 x 15 cm with an increase of 15 cm on either way indicated that the optimum spacing for obtaining higher yields at Coimbatore in Tamil Nadu is 45 x 45 cm (Varisai Muhammad and Subramanian, 1973). While, in the same State Sundaresan et al. (1977) advocated a spacing of 30 x 15, 45 x 15 or 30 x 30 cm for the red soil tract of Salem district both for rainfed and irrigated situations.

Rao et al. (1976 b) recommended a spacing of 45 x 20 cm for the Tirupati region in Andhra Pradesh. Makne et al. (1978) reported that the optimum plant spacing for higher yields in Maharashtra is around 30 cm with a row width of 30 - 45 cm. The optimum spacing for Bangalore was reported to be 60 x 45 cm (Giri Raj, 1983).

At Morden in Manitoba, Hoes and Huang (1976) observed that the sunflower yields increased with row spacings upto 180 cm with intra row spacings of 10, 20, 30 and 40 cm. Yields with 30 and 40 cm plant spacing with 180 cm row width were maximum.

Akhanda et al. (1979) reported that the effect of different row widths spaced 41, 61 or 91 cm apart with intra row spacings adjusted to give populations of 40,000; 60,000 and 80,000 plants per hectare had no significant influence on yield in Florida. The results indicated that the plant heights had a tendency to be higher with increased row widths and planting density. There was no effect on the number of leaves and head diameter. From the same experiment in the subsequent year, Smith et al. (1981) reported that the yields were highest with 41 cm row width treatment than with 61 or 91 cm. Row width was reported to have little effect on leaf size but plants in wider rows had more living leaves per plant and the plant height tended to increase with wider rows.

2.2.3.4 Effect of spacing variables at constant plant population

Literature on row width and plant spacing variables at constant plant population is meagre. Vijayalakshmi et al. (1975) conducted field trials on the crop geometry of sunflower at Hyderabad and Saskatchewan, Canada under dryland conditions. At Hyderabad, the cultivar - 'EC 68415' was evaluated with row widths of 37, 45, 60, 90 and 135 cm at a constant plant population of 75,000 plants per hectare. In the subsequent year the cultivar - 'Sunrise' was planted at 40, 60, 90 and 135 cm giving plant population of 37,000; 44,000; 56,000 and 74,000 plants per hectare. They concluded that there were no significant differences in seed yield or harvest index due to differential row width configurations at a constant or different level of plant population. At Canada, the cultivar - 'Krasnodarets' was evaluated for row spacings of 36, 53 and 89 cm at three planting densities of 25,000; 75,000 and 1,25,000 plants per hectare. Plants in the narrow row spaces were reported to grow taller, but there were no significant differences in the number of leaves per plant at different stages of crop growth. The row widths were not critical to vary the seed yield at any population, while population effects on yield were conspicuous.

Char and Dasgupta (1977) reported that the cultivar - 'Peredovik' raised in rows 40, 50 or 60 cm apart with plants spaced 35, 30 or 23 cm in the rows to obtain similar plant population per hectare did not affect the yield or yield attributing characters viz., plant height, number of leaves, test weight, head diameter and number of seeds per plant.

2.2.3.5 Effect of crop geometry on oil per cent and oil yield per hectare

Information on the effect of planting geometry by a change in row width and plant spacing variables is of vital significance since the oil per cent and the oil yield are the ultimate considerations upon which the economic value of the harvested marketable produce depends upon. But literature on this aspect is very scanty. Vijayalakshmi et al. (1975) reported that the oil per cent of sunflower seeds was not influenced by the row width variables in the range of 36 to 89 cm at populations of 25,000, 75,000 or 1,25,000 plants per hectare. This trend was later confirmed by Char and Dasgupta (1977). They also reported that the row widths of sunflower spaced 40, 50 or 60 cm apart at a constant plant population had no significant influence on oil per cent or oil yield per hectare. Likewise, Smith et al. (1981) reported that the oil per cent in sunflower seed was not influenced by the row width variation in the range of 41 to 91 cm at different levels of plant population. However, they observed that the oil yield per hectare was maximum with 41 cm row width and depressed at wider row spaces.

Working on the spacing variables Ramaswamy et al. (1974 b) observed that the plants spaced 15, 22.5 or 30 cm in rows grown 60 cm apart did not influence the oil per cent of sunflower. Similar conclusions were drawn by Beard et al. (1976). They reported that the oil per cent in plants spaced 10 to 40 cm within 60 cm row widths did not differ significantly. Beard and Ingebretsen (1980) also observed that the oil per cent was not influenced by spacing the plants 10 to 40 cm within the rows grown 76 cm apart. Oil yield on the other hand was depressed at 10 cm spacing while no differences existed with wider plant spacings of 20 to 40 cm.

The effect of spatial configurations appear to have no significant influence on the per cent concentration of oil in the seeds. While, oil yield per hectare rarely responded to the row width and plant spacing variables due to the variation in seed yield.

2.2.3.6 Effect of planting pattern

Pairing of rows has most frequently been employed in intercropping research with much success to accomodate the intercrops more efficiently in the interspace between the pairs than in conventional equidistant plantings. However, no ample work seems to have been taken up in sunflower with regards to the paired row pattern in comparison to equidistant rows either in solid or mixed stand. The limited literature available postulates that pairing is not advantageous in sunflower. From rainfed trials at two locations, viz., Jodhpur (Singh and Singh, 1977) and Maharashtra (Nikam et al., 1984) in India and from the tests conducted thrice at Darling Downs in Queensland(Radford, 1978) it was observed that the paired row pattern was not superior to the evenly spaced rows of sunflower. The results of experiments reported by Robinson et al. (1982) from the United States also supported these findings. They reported that the plants spaced in pairs did not support each other; they lodged more and yielded less than uniformly spaced single plants. Their results further strengthened the observations of Hoes and Huang (1976) that the stem rot disease spreads by root contact and hence the contact may be delayed by wide equidistant spacings.

2.2.4 Neutro-periodism

The per cent concentration and uptake of nutrient elements in plant parts of sunflower at different stages of crop growth have been reported to vary greatly by a large number of factors like planting date, fertilizer application, available soil moisture, temperature and many other agronomic practices as cited by Mathers and Stewart (1982). But literature on the comparison of nutrient composition and uptake in sunflower grown at varying crop geometry in sole or intercrop system is not available.

2.2.4.1 Nutrient concentration

From a field trial on the neutro-periodism of sunflower studied at Rajendranagar, Rao (1974) reported that the per cent concentration of nitrogen and phosphorus in the plant parts of sunflower, viz., leaf, stem and head decreased with crop age till maturity. Potassium in the leaf and stem was highest in the early vegetative phase, declined gradually till seed filling and again increased at maturity. In heads it followed a consistent decline till maturity. But, the observations of Llyod et al. (1980) from field studies selected over 25 locations representing a wide range of soil types and hybrids in North Dakota corroborated that of Robinson (1970) for shifts in nutrient content of leaves as plant ages. They reported that potassium in the leaves generally declined in concentration with age from flowering stage. Seiler (1984) compared the nutritional parameters of wild and cultivated sunflower in the Texas high plains and concluded that the potassium concentration generally decreased as plants matured.

Robinson (1978) reviewed that the elemental concentration in sunflower are high in the young plants and decreased to maturity. Nitrogen per cent in tops of the plants declined with advance in age of the crop. Phosphorus increased in concentration upto heading and then declined abruptly. Potassium concentration was lowered with crop age upto flowering, but increased again at harvest.

In a nutritional evaluation trial of sunflower conducted during the summer seasons at Meerut, it was observed that the per cent nitrogen, phosphorus and potassium in the plant were high in the initial stages of growth. These mineral elements in the plant tissue then dropped off slowly and steadily with advance in age of the crop till maturity (Kalra and Tripathi, 1980).

Hanumantha Rao and Vidyasagar (1981) reported that the nitrogen concentration in leaves, stem and petioles of two sunflower cultivars - 'EC 68414' and 'EC 68415' studied at Bapatla in Andhra Pradesh were maximum at the early vegetative stage and reduced to a minimum at harvest. The pattern of phosphorus absorption was, however, different from the earlier reports. In leaves phosphorus concentration was maximum at the vegetative phase, declined at flowering and again increased at harvest. But, the concentration in stem and petioles increased upto flowering and declined at maturity. Potassium concentration in leaves and stem declined with crop age while in the petioles it was maximum at flowering.

The per cent nitrogen in leaves, stem and head of the hybrid sunflower '896' grown on the clay loam soils of the Bushland Laboratories in Texas was reported to confirm most of the earlier findings. The tissue concentration of nitrogen in the plant parts declined consistently with crop age till harvest. Phosphorus also declined with crop age in different plant parts. But, in the heads it increased again at maturity. Potassium followed a declining trend in heads and stem. In leaves the concentration increased gradually with crop growth and declined at harvest (Mathers and Stewart, 1982).

From a glass house experiment in New South Wales, Hocking and Steer (1983 b) demonstrated that the phosphorus and potassium concentration decreased markedly in the roots, stem and leaves of sunflower as plants aged. Phosphorus also decreased with crop age in the capitulum but the concentration of potassium increased substantially.

Reddy and Patil (1983) reported that the nitrogen concentration of 'BSH-1' a hybrid sunflower grown at Bangalore increased upto flowering and then declined appreciably at harvest. The increase at flowering was interpreted to the greater absorption and accumulation of this element due to top dressing at 40 days. Phosphorus concentration in the plants declined with crop age confirming most of the earlier findings.

2.2.4.2 **Nutrient uptake**

The quantity of nutrients required by the plants varies with their physiological and growth habits. Lochwing (1961) reviewing the work of different authors stated that the rate of absorption of a particular ion is determined not only by its availability in the substrate but also by the concentration of these already in the plant. Sunflower possesses the habit of uptake of nitrogen more than its requirement when the external supply is abundant. Coic et al. (1972) also reported that the high level of nitrogen nutrition throughout the vegetative cycle resulted in high content of nitrogenous compound in several parts of sunflower. Mathers and Stewart (1982) established that the roots of sunflower penetrate deeper than many crops, however, and may obtain nitrogen that had moved below the normal rooting zone. Blamey et al. (1978) made a mention that the plant species and even cultivars within species may vary appreciably in the pattern of nutrient uptake and the tissue requirement for a certain nutrient.

Karatson and Boshkanyan (1966) stated that the nitrogen uptake in sunflower was greatest in the early vegetative stage which was complete by the end of flowering, while the uptake of Phosphorus and Potassium continued till the end of flowering reaching a peak during flowering. From field experiments on the nutrient uptake pattern of sunflower in France, Gachon (1972) found that most of the nutrients were absorbed during the month before and the month after the beginning of flowering. Vrebàlov (1974) reported that the uptake of nitrogen in sunflower reached the maximum at about full anthesis. Absorption of phosphorus from the soil continued after full anthesis but uptake of potassium ceased.

Rao (1974), on the other hand reported that the uptake of nitrogen, phosphorus and potassium in sunflower plants closely followed the pattern of dry matter accumulation. The uptake of these elements was most rapid at the bud stage and reached the maximum at harvest. However, their absorption was reported to be practically completed by the end of flowering. Nitrogen and potassium in the leaves increased upto flowering and declined thereafter. But, the uptake of nitrogen both in the stem and head increased gradually till harvest. Phosphorus in leaves and stem increased till the bud formation stage and then declined consistently till harvest. Potassium was removed in higher quantities both by the stem and head with advance in crop age. These findings were subsequently confirmed by Kalra and Tripathi (1980) at Meerut. They also observed that the uptake of nitrogen, phosphorus and potassium in the sunflower plants increased with crop age.

Mathers and Stewart (1982) reported that the uptake of nitrogen as well as phosphorus in the leaves and stem increased until seed filling and then decreased as it was translocated to the heads. Uptake of potassium increased upto flowering, slowed down in the later stages but again some uptake occured until the plants reached maturity.

Hocking and Steer (1983 a) reported that the amount of nitrogen in the capitulum was greatest at full anthesis whereas in roots, stem and leaves it was highest at the start of flowering. Their study indicated that the nitrogen uptake by sunflower plants occured well into seed filling with about 35% of the total nitrogen accumulating in the period from 3 row anthesis when 75% of the seeds had filled. These results suggest that the enzyme system associated with nitrogen metabolism are still functional during early senescence. They observed that throughout growth of the plants, stems accumulated much smaller quantities of nitrogen than did leaves, despite the large contribution of stem to the plant dry matter. From another experiment concerning the uptake and distribution of mineral elements, Hocking and Steer (1983 b) observed that the uptake of phosphorus and potassium by whole plants occured until about 10 days before seed maturation. The accumulation of these elements was most rapid during the period from flower bud visible to full anthesis.

2.3 GROUNDNUT

2.3.1 General pattern of crop growth and phytomass accumulation

The pattern of crop growth and phytomass accumulation in groundnut varies with the habitat group to which it belongs. Ramayya (1984) observed that the leaf area per plant increased with crop age till the maximum was attained at 45 days in valencia types, upto 60 days in spanish and 75 days in virginia. This was followed by a consistent decline from active pod filling stage till harvest. The phytomass accumulation in whole plant as well as that partitioned into leaves or stem revealed a similar pattern.

2.3.2 Response of groundnut to plant population

Crop management technology for optimum yields is an important factor in expanding the groundnut acreage and production to abridge the gap between demand and the short-fall in supply of vegetable oils in the country. The most important aspect is choosing a plant density that will maximise the seed and oil yield and minimise the seed costs. However, optimum density requirement is largely influenced not only by the environment and genetic factors but also by the growth habit of different groundnut cultivars. Literature on this aspect is, therefore, reviewed to expedite the available information on the behaviour of groundnut in relation to planting densities.

Elango and Nagarajan (1977) tested the performance of groundnut cultivar - 'TMV-7' over a range of 93,000 to 8,33,000 plants per hectare under rainfed farming in Tamil Nadu. The study indicated that the lowest population recorded the least yield per hectare inspite of the highest pod production per plant. Pod yield increased with a rise in planting density upto 4,18,000 plants per hectare but declined with a subsequent increase to 8,33,000 plants per hectare. Two years later Gopalaswamy, et al. (1979b) elucidated the results of this trial continued over five rainy seasons through a fitted equation of the curvilinear nature. Since there was no positive yield response to an increase in population beyond 4,18,000 plants per hectare, the quadratic response function was fitted which indicated that the agronomic optimum level of plant population was 6,48,000 plants per hectare for maximum physical production. But, the economic optimum plant density for most profitable level of production worked out to 4,00,000 plants per hectare. The number of pods per plant was maximum with lowest population of 93,000 plants per hectare and least with highest density of 8,33,000 plants per hectare. The increase in number of pods per plant at lower populations did not compensate for the loss in yield on account of reduced population per unit area. Test weight of the kernels also increased significantly at lower populations.

Trials conducted at three locations in Nigeria indicated that the change in plant population had a striking influence on pod yield of groundnut. Production of pods and haulms was markedly increased by cropping at planting densities upto 2,15,000 plants per hectare over the recommended population of 43,000 plants per hectare (Yayock, 1979 a). Increasing plant density resulted in suppression of the biological yield of individual plants, but production increased on the basis of unit land area (Yayock, 1979 b).

In Canada, Roy et al. (1980) realized a higher yield potential of groundnut in the range of 1,80,000 to 4,60,000 plants per hectare. At still higher density of 5,70,000 plants per hectare the yield was reported to be significantly affected.

Reddy *et al.* (1984) recorded significantly higher yield of TMV-2, cultivar of groundnut at a population density of 3,33,333 plants per hectare than at 5,00,000 plants per hectare grown under rainfed conditions on the sandy loam soils of Hyderabad. But, at Tirupati, Venkateswarlu *et al.* (1984 a) obtained maximum pod yield of this cultivar with a density of 5,00,000 plants per hectare which was on par with 10,00,000 plants per hectare. But at a lower population of 3,33,333 plants per hectare the yields were reported to be significantly lowered.

Raju *et al.* (1985) registered a consistent increase in pod and haulm yield of groundnut cultivar - 'Robut 33-1' with increase in population density from 2 to 4 lakh plants per hectare. However, it was concluded that the yield differences between 3.33 and 4 lakh plants per hectare were not significant.

In an excerpt on the research highlights in Tanzania, pod yield per plant was shown to decline with increase in density from 50,000 to 2,50,000 plants per hectare. Conversely, yield per hectare increased with density. The relationship being quadratic, virginia type of groundnut showed an yield plateau with little differences while response to an increase in density was marked with spanish group. It was concluded that the potential yield of spanish cultivars can be realised with population of around 2 lakh plants per hectare (Taylor, 1985.

2.3.3 Response of groundnut to crop geometry

Since groundnut cultivars vary in their growth habit, it is unlikely that any one combination of spacing in the row and row width would be optimum for all varieties which also very much depends on fertility of the soil and various other climatic conditions (Cox and Reid, 1965 and Reddy, 1982). Methods of achieving the optimum plant population have long been studied. As early as 1917, Morel working in Southern France recommended that the optimum population be manipulated through the row width adjustment. But, Beattie et al. (1927) recommended that the spacing of plants within the rows should be ajusted. While, the recent view of Reddy et al, 1982) held the earlier opinion that the spacing between the rows should be manipulated since intra-row spacings have less effect on yields particularly when moisture is a limiting factor. Literature is therefore gathered to have an insight on the performance of groundnut to spacing manipulation within and/or between the rows.

2.3.3.1 Effect of row width at constant plant spacing

Plant spacing between the rows is an important critical yield regulating variable. Narrow rows entail an unnecessary extra expenditure on the cost of seed material while the area not covered by the plants due to wider rows is the area wasted with an apparent yield reduction. The optimum spacing that gives maximum yield therefore needs to be evaluated for different genotypes and a set of environment. A review of work done in this regard provides an understanding of the crop's behaviour to a variation in row spacing.

The performance of irrigated groundnut to row width variables of 30, 45 and 60 cm tested at the central Arid Zone Research Institute indicated that the number of leaves and dry weight per plant tended to increase with wider row spaces. The favourable effect of increased spacing was also seen on fruit development where the weight of pods per plant, shelling per cent and hundred kernel weight were higher (Bhan and Misra, 1972).

A comparison of three row width variables of 30, 60 and 90 cm at an intra-row spacing of 30 cm in Tanzania revealed that the increased planting density through a decrease in the row spacing led to heavier yields. Groundnut cultivars belonging both to bunch and runner habitat responded similarly recording highest yields at a spacing of 30 x 30 cm. Number of pods per plant decreased with decrease in the row widths and were maximum with the widest rows (Enyi, 1977).

From a two-year field study with irrigated bunch cultivar - 'Co-1' of groundnut at Tindivanam, Gopalaswamy et al. (1979 a) concluded that the pod yield of groundnut in rows spaced 22.5, 30 or 40 cm apart given a spacing of 10 cm within the row was almost similar. However, the response pattern was discriminant when the plant spacing was raised to 15 cm. Significantly highest yields were obtained with the closest row width of 22.5 cm than the other row spaces. Rajah (1981) reported that the yields of this cultivar grown under rainfed conditions was not influenced by row width variables of 20, 24 or 30 cm given a spacing of 8 or 10 cm between the plants within the rows. But, increase in the row spacing to 40 cm significantly reduced the pod yield per hectare. Chavan and Kalra (1983) also observed that the pod and haulm yield of groundnut grown under rainfed conditions at Dapoli in Maharashtra was significantly more at a row spacing of 30 cm than at 37.5 cm with a plant spacing of 15 cm. Weight of pods per plant, hundred kernel weight, shelling per cent and oil per cent were favourably influenced by the wider row spacings.

Promising yield response to a reduction in row width from 30 to 20 or 10 cm was obtained from an irrigated trial given within the row plant spacing of 10 cm at Tirupati. It was concluded that the row spacings of 10 to 20 cm would be optimum for higher yields as the production of pods from rows spaced 30 cm apart was significantly depressed. The yield of haulm decreased significantly as the rows were spaced distant apart (Rama Rao et al. 1982). Later, Rama Rao et al.(1983) and Venkateswarlu et al.(1984 a) reported that the total number of pods, number of filled pods and yield per plant in this trial increased with row spacing. While, in a subsequent publication, Venkateswarlu et al. (1984 b) reported that the oil content of the kernels increased with increase in spacing but the out-turn of oil per hectare was maximum with 20 cm row spacing.

2.3.3.2 Effect of plant spacing at constant row width

Intra-row spacing in groundnut has a less pronounced influence on the pod yield than the inter-row spacings. Roy et al. (1980) studied three seed spacings of 5.08, 10.16 and 15.24 cm in rows 41 cm apart in the Southern Ontario. Closer seed spacing resulted in higher yields than wider spacings at both early and late plantings of groundnut.

A six year yield trial with six genotypes of groundnut grown under irrigated conditions was established at Florida in Gainsville during the period from 1976 to 1980. Three genotypes showed no significant yield differences among spacings of 10, 15 or 30 cm in rows spaced 91 cm apart. Two cultivars produced the same yields at 10 cm spacings as they did at 15 cm and both cultivars showed a significant yield reduction at 30 cm spacing. In one variety yields were significantly higher at 15 cm than at 30 cm while, the yield at 10 cm was intermediate, but was not significantly different from either 15 or 30 cm (Knauft et al. 1981).

Reddy et al. (1983) reported that the virginia runner groundnut (Kadiri-1)did not reveal a differential response in pod or haulm yield to within the row plant spacings of 8.3, 12.5 or 16.7 cm in rows spaced 45 cm apart. The production was however, significantly reduced compared to 12.5 cm as the plant spacing was increased to 25 cm. Compensation to intra-row spacings among 6.3, 9.4 and 12.5 cm did occur even in rows 60 cm wide, but yielded significantly less than 9.4 cm with increase in plant spacing to 18.8 cm. The trial thus indicated that compensation to yield occured at narrow intra-row spacings irrespective of the row widths tested.

A similar trial conducted at Dharwar with three test genotypes indicated that the plants spaced 10, 15 or 20 cm in row widths of either 30 or 40 cm had no significant influence on the pod yield of groundnut (Mani et al., 1984).

2.3.3.3 Effect of change in spacing within and between the rows

Summarizing the results on the yield of semi-spreading groundnut from 16 experiments, Cox and Reid (1965)concluded that greater and more consistent increase in yields were obtained by reducing the row width than by increasing the number of plants per meter of row. Row width variation from 30 to 90 cm and plant to plant spacing varying from 15 to 60 cm indicated that the narrow spacings offered an advantage of increased yield and weed suppression.

Working on the spatial requirement of irrigated groundnut, Naidu (1968) and Varisai Muhammad and Dorai Raj (1974) recorded higher yields with the closest spacing of 15 x 15 cm under the Nagarjunasagar Project Area at Amravathi in Andhra Pradesh and in Coimbatore respectively.

Wynne et al. (1974) observed that the inter-row spacings of less than 91 cm did not significantly influence the yield and had little effect on fruit size of Virginia type peanuts. The crop produced little higher yields at 12.7 cm than at the 25.4 cm intra row spacing with no significant differences in the three year study.

Elango and Nagarajan (1977) reported that the pod yield per hectare increased with plant spacing from 8 to 24 cm at 15 cm row width. While at higher row widths of 30-45 cm higher yields were recorded at the closest plant spacing of 8 cm.

Among the various spatial configurations tried for a pre-released culture of bunch groundnut-'AH 8254' at Tindivanam, Gopalaswamy et al. (1979 a) obtained significantly highest yields from a spacing of 30 x 10 cm. The yields decreased with increase or decrease beyond the optimum spacing. Closer spacing of 30 x 15 cm were also reported to yield significantly higher than 45 x 15 or 30 x 30 cm under irrigated conditions in field experiments conducted at Dapoli in Maharashtra (Kalra et al., 1984).

Roy et al. (1980) conducted an experiment at Ontario with five row widths - 41, 61, 81, 102 cm and a twin row 61-31 cm planted at four plant populations of each 1,80,000; 3,30,000; 4,60,000 and 5,70,000 plants per hectare. The narrowest row width of 41 cm produced the highest yield of pods and kernels. Pod yield with densities of 1,80,000 to 4,60,000 plants per hectare were not significantly different but were higher than the pod yields obtained with a higher density of 5,70,000 plants per hectare.

Chin Choy *et al*. (1982) studied the response of groundnut to row width and plant spacing variables at Oklahoma under rainfed and irrigated conditions. Row spacings were 25, 50, 75 and 100 cm. Within row plant spacings ranged between 2 and 27 plants per meter. The fitted surface response equation indicated that the 25 cm row spacing gave the highest yield of pods both for irrigated and non-irrigated conditions. Approximately 15 plants per meter was the optimal plant spacing in all row spacings for maximum yield.

2.3.3.4 Effect of spacing variables at constant plant population

Available information on the influence of a change in shape of the feeding zone of the plants by a change in row width and plant spacing of groundnut at a given density is reviewed to explore the possibility of spacing manipulation. The work of Elango and Nagarajan (1977)indicated a dramatic variation in the pod yield of groundnut due to change in the spatial arrangement at a given density of plant population per hectare. With 4,17,000 plants per hectare, pod yield was much reduced in plants spaced 15 x 16 cm than in 30 x 8 cm. Similarly, a remarkable reduction was also evinced with a spacing of 45 x 8 and 45 x 16 cm than the plant arrangement of 15 x 24 and 30 x 24 cm at a corresponding density of 2,78,000 and 1,39,000 plants per hectare.

But Venkateswarlu, *et al*. (1980) recorded no significant yield reduction of pods with plant spacing of 30 x 5 cm than the conventional spacing of 15 x 10 cm under irrigated conditions. The plant population was 6,66,000 plants per hectare for both the spatial arrangements. It was also reported that the oil yield as well as the protein yield per hectare did not differ markedly.

At a constant plant population of 1,48,000 plants per hectare under rainfed conditions, the spatial arrangement of plants in 45 x 15 or 60 x 11.25 cm was not effective in bringing about a significant change in the yield of pods and haulms at Parbhani (Bhosle, 1984).

2.3.4 Neutro-periodism

Reports on the pattern of nutrient absorption and accumulation in the plant parts of groundnut over the crop growth period are not consistent and often conflicting. The per cent tissue concentration, uptake and distribution of nutrients in the plant parts are greatly influenced by the edaphic factors (Virmani, 1973), genotype (Williams,1979a), environment (Nagaraj and Kailash Kumar, 1983) and other agronomic manipulations (Giri and Upadhyay, 1980; Chavan and Kalra, 1983 and Singh and Ahuja, 1983).

2.3.4.1 Per cent nutrient composition

In an attempt at the physiological characterization of groundnut, Rao *et al*. (1974) recorded a marked variation in the tissue concentration of nutrient elements in the plants belonging to different habitat groups. They established that the percentage nitrogen was highest in Virginia, phosphorus in Valencia and calcium in the spanish group.

From a physiological evaluation of four varieties of groundnut at the salisbury Research Station in Rhodesia, Williams (1979 b) inferred that there were no major differences in the per cent nitrogen of leaves, stem, husks or kernels. But, accumulation of nitrogen by the crop differed with varieties. It continued till maturity in the cultivar 'Jacana', ceased 4 weeks before maturity in Valencia 'R-2', 18-20 weeks before in the cultivar 'Florunner' and 20 weeks before in 'Erget'.

Studies on the neutro-periodism of groundnut indicated that there are two critical periods of nitrogen concentration. Putnamkar and Bathkal (1967) observed that the cultivar 'AK-12-74' grown on the black cotton soils of Nagpur had two peaks of nitrogen concentration in the plant corresponding to the flowering and pod development stage of the crop. The concentration of phosphorus was reported to increase with the development of the plant. At harvest, the concentration of both nitrogen and phosphorus was more in the seeds followed by leaves and shoots, while the highest concentration of potassium was observed in leaf followed by seed and shoot. But, Padalia and Patel (1984) reported that the concentration of nitrogen and phosphorus in different plant parts at harvest were in the order of pod, shoot and root. Shoot accumulated more potassium and only a small part of it was translocated to the pods.

Two peaks of nitrogen concentration in 'TMV-2' cultivar of groundnut were also observed a year later from a pot culture study at Coimbatore (Gopalakrishnan and Veerannah, 1968). But, the peaks coincided with seedling and mid-flowering stages both in the leaf and stem as well as in the whole plant. This was followed by a gradual decline towards maturity. Initially phosphorus per cent increased to a maximum in the leaves at pre-flowering but declined subsequently till maturity. In stem the concentration was maximum in the seedling stage, declined at pre-flowering, improved at mid-flowering and then declined consequently till maturity. The whole plant showed that the phosphorus concentration declined progressively with crop age. Potassium concentration in the leaves was maximum in the seedling stage but declined in the later stages. In the stem it was maximum at pre-flowering phase. The whole plant revealed an increasing concentration of potassium with crop age upto mid-flowering followed by a rapid decline towards maturity. The per cent concentration of nitrogen and phosphorus were high in the leaves and of potassium in the stem. Kernels were rich in nitrogen and phosphorus while shells contained higher per cent of potassium than the kernels. The uptake of nutrients increased at a faster rate from 30 days after sowing. Leaves removed substantially increasing amount of nitrogen than the stem with advance in crop age. Phosphorus uptake was not considerable throughout the growth period. A notable feature of potassium was that it accumulated to a considerable degree in the stem and not in the leaf.

Chahal et al. (1983) attained similar results in the pattern of nutrient absorption particularly nitrogen and potassium in different plant parts of the cultivar 'M-145'. Their study on the neutro-periodism from a green house trial at Hissar revealed that the nitrogen concentration in leaves was higher at 3 leaf (10 days) and flowering stages (50 days) than the later stages. The pattern of phosphorus concentration was similar to nitrogen except that it showed an increasing trend towards maturity. Increase in nitrogen and phosphorus concentration in the stem was noted towards maturity. The concentration behaviour of potassium was different from nitrogen and phosphorus. In leaves it was highest in early stages and in stem at 30 days of plant growth. Later it declined continuously till maturity. But, Soundara Rajan et al. (1984) working on 'TMV-2' cultivar of groundnut, a spanish bunch type on the sandy loam soils at Tirupati recorded that the concentration of potassium was high at 35 and 65 days followed by a decline at harvest.

The pattern of nitrogen absorption by the cultivar 'Erget' grown at the Salisbury Research Station in Rhodesia was distinctly different from the above reports. Williams (1979 b) observed that the leaf and stem nitrogen content decreased steadily from 51 to 100 days after sowing and thereafter remained fairly constant until maturity (180 days). Nitrogen content of the husk decreased steadily, while that of kernels increased gradually. The accumulation of nitrogen in leaves and stem started to decline in amount shortly after the start of reproductive growth. Total nitrogen accumulated by the crop reached a maximum at about 150 days and declined thereafter.

2.3.4.2 Nutrient uptake

The uptake studies in pot culture at Rajendranagar showed that the bunch strain of groundnut, 'TMV-2' removed larger quantities of nitrogen and potassium with crop age. Phosphorus in the whole plant was maximum at pod formation but declined abruptly at maturity (Sham Sunder and Vittal Rao, 1980).

Nagaraj and Kailash Kumar (1983) studied the nutrient uptake of 'TMV-10' a bunch Virginia cultivar of groundnut at the National Research Centre for Groundnut in Tambawadi at Junagadh. Plant samples showed that the accumulation of nitrogen, phosphorus and potassium were higher in the third month of crop growth during which time the pod formation started. Dry matter and nutrients which were concentrated in the leaves in the first month (62-69) moved to the stem during the second month and finally got partitioned to the pods to the extent of 8-27 and 27-44% respectively in the third and fourth months of plant growth. Nitrogen uptake was gradual in the first two growth phases and increased abruptly in the third and fourth months. With a gradual activity in the first two months phosphorus reached the peak in the third month and slightly declined later on. Potassium uptake increased gradually throughout except for a marginal decrease in the final growth phase. There was a greater activity for all the nutrients examined during the pod formation stage (60 - 90 days) stage.

2.3.4.2.1 Effect of planting geometry

The spatial configuration of groundnut sown with varying row widths and plant spacings seem to influence the per cent absorption and accumulation of the mineral elements. Chavan and Kalra (1983) reported that the groundnut cultivar TG-1 at Konkan recorded a higher percentage each of nitrogen, phosphorus and potassium in the wider row spacing of 45 cm than 37.5 and 30 cm with a constant intra-row spacing of 15 cm. But, the uptake of these nutrients was higher in closer spacing of 30 cm.

Bhosle (1984) observed that the per cent nitrogen in different plant parts of groundnut cultivar M-13, viz. leaf, stem and kernel or shell did not change by planting in equidistant or paired row pattern nor by the geometry with spacing of 45 x 15 cm and 60 x 11.5 cm at Parbhani.

Singh and Ahuja (1985) reported that the uptake of nitrogen and phosphorus in the groundnut cultivar T-64 grown at a row width of 45 cm was maximum when the plant spacing was 15 cm than at 10 or 20 cm.

2.4 INTERCROPPING

Intercropping has been considered as a potentially beneficial system of crop production and an age old practice in India. The concept of intercropping to safeguard against total failure of the crops has now changed to maximise production per unit area per unit of time, owing to the availability of crop varieties of different maturity durations and growth rhythms, plant protection measures and fertilizers (Singh, 1979). Intercropping has been defined as the growing of two or more crop species simultaneously on the same field (Willey, 1979 and Robinson, 1984).

The flexibility of sunflower to adjust to a range of population densities and an array of geometry to varying row width or plant spacings at constant or different levels of plant population make it an admirable crop for introducing additional crops in the inter-row spaces. Since, the crop is of recent introduction to Indian Agriculture and also by virtue of its aggressive growth habit not much work has been done on the aspects of intercropping in sunflower. The limited literature available on the effects of each crop component, the overall productivity and monetary returns are reviewed for an understanding of its potential in the intercrop system.

2.4.1 Effect of sunflower on other crops in intercrop system

Sunflower is considered an aggressive crop competing for a major share of the resources in an intercrop system due to its prolific growth habit. In addition to its strong competitive ability, Rice (1974) reported that the crop has allelopathic effects on the companion species. While, Robinson (1980) considered that this effect however is of no major concern in field conditions.

2.4.1.1 Effect of sunflower as main crop

Chandrasekar and Morachan (1979 b) found that the sunflower crop smothered the growth of intercrops undersown with one row of cowpea or two rows of groundnut in the paired row interspaces. However, the competitive effect could be minimized with less severe yield reductions by sowing the inter-crops 7 - 14 days prior to sowing of sunflower.

In an intercropping experiment with various oilseed crops in Gujrat, sunflower was reported to have a drastic effect on the seed yield of sesamum. The competition was less severe with sunflower and sesamum sown in 1 : 2 than 1 : 1 row proportions (Desai and Goyal, 1980).

Umapathy *et al.* (1980) reported that the yield of groundnut, black gram and green gram intercropped with sunflower in the Belgaum district of Karnataka were reduced to about 38.72 and 69% of the respective sole crop yield.

Severe reduction in the pod yield of groundnut inter-cropped with sunflower was also ascertained by Nikam *et al.* (1984) in a later study at Jalgaon in Maharashtra. The average reduction over the three year study indicated a net loss of 72% pod yield when intercropped with sunflower in 1 : 1 ratio. The reduction in yield was less pronounced with increase in the proportion of groundnut rows.

Robinson (1984) reported that the intercrop competition with sunflower in strip intercropping was very injurious to corn and soybean but not to mustard. In row intercropping sunflower brought down the yield of soybean to 450 kg ha^{-1} from the recorded yield of 3050 kg ha^{-1} in sole cropping. Yield of field beans were also reduced to 150 kg ha^{-1} in contrast to 1250 kg ha^{-1} in the solitary stand.

Narval and Malik (1985) reported that sunflower was most harmful to groundnut and soybean and least harmful to green gram and cluster bean. However, the yield reductions were significant compared to the respective sole crops of all the four legume components.

2.4.1.2 Effect of sunflower as an intercrop

Experiments conducted at the IARI Regional Research Station, Hyderabad, indicated that sunflower had a smothering effect on sorghum and groundnut when intercropped in the paired rows of these species. It had brought down the grain yield of sorghum and yield of groundnut from 4190 and 3196 kg ha^{-1} in the respective sole crops to 1235 and 1100 kg ha^{-1} (Vijaykumar *et al*., 1973).

The base crop of sorghum intercropped with sunflower in subsequent studies at Parbhani (Shaik Mohammad, 1975) and Hyderabad (Satyanarayana and Reddi, 1979 and Tarhalkar and Rao, 1979) also experienced yield reductions to the extent of 20 - 75%. The crop growth and yield components of sorghum were also adversely affected in the intercrop system.

Venkateswarlu *et al*. (1980) found that the pod yield of groundnut was reduced from 21.6 q ha^{-1} in sole crop to 18.0 q ha^{-1} when intercropped with sunflower at Tirupati.

Sunflower sown as an intercrop with groundnut in 6 : 2 proportion at Bangalore similarly exercised a severe competition. Groundnut was reported to have suffered due to a highly significant reduction in the yield of pods. Morden- the short statured, low yielding and early maturing cultivar of sunflower had a relatively lesser competition than the taller, high yielding and late maturing cultivar - 'EC-68414' (Sindagi, 1982).

2.4.2 Effect of intercrops on sunflower

Singh and Singh (1977) reported that intercropping of green gram, cowpea, moth bean and groundnut did not affect the seed yield of sunflower significantly. Marked reduction in yield was however, recorded when cluster bean was grown as a companion crop. Ujjanaiah et al. (1981) also observed that the yield of sunflower did not decrease due to intercropping with groundnut.

Nikam et al. (1984) reported that the reduction in seed yield of sunflower in general was not significant with groundnut intercropped in the uniform, paired or skipped rows of sunflower.

Working on the intercropping of sunflower with different plant populations at Minnesota, Robinson (1984) observed that the crop with 52,000 plants per hectare yielded the same with or without a soybean intercrop and the seed quality was not affected significantly. At lower population densities of 22,000, 15,000 and 8,000 plants per hectare yields of sunflower were lower and those of soybean higher.

Competitive effects of intercrops causing a substantial reduction in the seed yield of sunflower has also been recorded in literature. Chandrasekar and Morachan (1979 a) reported that the seed yield of sunflower was reduced due to competition by one row of cowpea or two rows of intercropped groundnut. The reduction was more when the intercrops were sown earlier than the sunflower due to their better establishment. Capitulum diameter and number of seeds per head were also reported to decrease by intercropping. But the thousand seed weight was not affected by the planting system.

Umapathy et al. (1980) reported that the black gram intercropped with sunflower (2 : 3) was less competitive causing a reduction in yield of sunflower by 20% as compared to 30 and 35% by green gram and groundnut respectively.

Sindagi (1982) observed that the yield of sunflower in intercropping system with groundnut was reduced to 80% of the sole crop yield in the first year while the reduction was further augmented with only 45% of the sole crop yield recorded in the second year.

At Hissar, Narval and Malik (1985) observed that the legume components, viz., soybean, cluster bean, groundnut or green gram sown as intercrops by replacing every alternate row of sunflower significantly reduced the seed yield of the latter. Cluster bean was more competitive than the other legumes. However, the oil per cent of sunflower was not influenced by intercropping.

2.4.3 Total productivity and monetary returns in intercrop system

Vijaykumar *et al.* (1973) reported that the marked reduction in seed yield of sorghum intercropped with sunflower could not compensate for the loss by the additional gain in yield of sunflower. The total productivity from the intercrop system was 44% less than the sole crop yield of sorghum, which consequently accrued a monetary loss of 27%. But, the reduction in yield of groundnut was reported to be more than compensated by the additional yield of the sunflower as an intercrop component accounting for 12% higher productivity than the sole crop yield of groundnut. The monetary gains were also highly encouraging with 43% extra returns over the sole crop.

Combination of sunflower with sorghum as the companion crop at Parbhani, similarly indicated that the total productivity as well as the net returns per hectare were reduced by 10 and 7% compared to the sole crop of sorghum (Shaik Mohammad, 1975).

Tarhalkar and Rao (1979) also proved that the intercropping of sorghum with sunflower is disadvantageous. They observed that the total productivity was brought down to 26.38 q ha^{-1} from the sole crop yield of 41.25 q ha^{-1} in sorghum. The LER was less than unity (0.88) and the total returns per hectare were also considerably lower than the sole crop. But, Satyanarayana and Reddi (1979 and 1981) reported that though the total productivity was about 9% less the net income by intercropping sorghum with sunflower increased by 18% over the sole crop of sorghum.

Lakhani (1976) and Willey and Lakhani (1976) observed that the combination of comparable duration - sunflower and fodder radish - in different proportions and populations is a productive proposition. The results of field trials indicated that all the systems out-yielded the pure stands at the same population level, except for the predominantly fodder radish mixture. The pre-dominantly sunflower mixture gave the highest yields achieving land equivalent ratios of 1.08, 1.13, 1.20 and 1.25 from the lowest to the highest populations.

Under rainfed farming at Jodhpur, Singh and Singh (1977) reported that the total productivity of intercropping systems was 75% higher than the pure cropping of sunflower. Intercropping sunflower with cowpea gave the highest productivity followed by green gram, groundnut and moth bean as intercrops. The highest additional monetary returns were obtained from sunflower + cowpea followed by sunflower + greengram and sunflower + groundnut intercropping systems. Sunflower + moth bean and sunflower + cluster bean intercropping systems gave only marginal additional returns over the pure cropping of sunflower.

Kalawatia (1979) from Akola reported that the highest seed yield and monetary returns were obtained from the intercropping system of groundnut and sunflower sown in 6 : 2 proportion. While, Kachapur et al. (1980) reported that the intercropping of sunflower with niger is most profitable at Bangalore.

Desai and Goyal (1980) observed that though the productivity of oilseeds was more, intercropping sunflower with sesamum in 1 : 1 or 1 : 2 proportions was less remunerative than the pure crop of sesamum in Gujrat.

Venkateswarlu et al. (1980) reported that the reduction in pod yield and oil content of groundnut intercropped with one row of sunflower was compensated with the resultant increase in total productivity of grain, oil content and protein yield from the mixture over pure crop of groundnut. The net returns from the intercrop system were higher (Rs 3375 ha^{-1}) than from the sole crop of groundnut (Rs 3264 ha^{-1}). But, Umapathy et al. (1980) on the other hand observed that the intercropping of sunflower and groundnut was not remunerative and fetched lesser net returns than either sole crops. While, intercropping sunflower with black gram was reported to be highly profitable.

Hosmani (1981) and Ujjanaiah et al. (1981) reported that sunflower and groundnut is the best combination for higher productivity and is more remunerative than either of the sole crops in the Badra basin of Karnataka.

The beneficial effects of intercropping sunflower with one or two rows either of groundnut or soybean on the total productivity were also recorded by Nagre (1981). But, intercropping sunflower with cowpea did not yield more than the sole crop yield of sunflower. The monetary returns increased by 28 and 33% when sunflower was intercropped with one or two rows of groundnut.

Sindagi (1982) obtained higher productivity and net returns by intercropping groundnut with the early maturity and short statured sunflower. But, both the total seed yield and returns from intercropping with the later maturity and taller genotype of sunflower were not superior to the sole crop of groundnut.

Inclusion of groundnut as an intercrop in row proportions ranging from one to five in the inter-row spaces of sunflower were reported to increase the total oilseeds and oil production. The monetary advantages were also substantially higher than the sole crop of sunflower, but was less profitable than the sole crop of groundnut (Nikam et al., 1984).

Robinson (1984) reported that the additional gain in yield of soybean in sunflower-soybean intercrop system increased the overall productivity more than the pure crop of sunflower but did not yield as much as soybean alone. With field beans the intercrop system was more productive than either sole crops at lower planting densities (22,000; 14,000 and 7,000 plants per hectare) of sunflower. But, with density of 52,000 plants per hectare the total productivity could not compensate for the yield reductions and was less than the yield of each sole crop.

At Hissar, Narval and Malik (1985) found that the land equivalent ratio was less than unity when every alternate row of sunflower was replaced with groundnut in the intercrop system. The mutual inhibition could not make up for the loss in yield of each component. Intercropping green gram with sunflower was reported to produce a maximum land equivalent ratio of 1.05.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

Investigations on "Crop geometry studies in sunflower in association with groundnut" were carried out for three seasons during summer and <u>kharif</u>, 1983 and summer 1984 at the Student's Farm, College of Agriculture, Rajendranagar. Simultaneously trials on optimum density requirement of sunflower grown alone or in association with groundnut were also conducted in a systematic design. Details of materials used and the techniques followed during the course of investigations are details in this chapter.

3.1 EXPERIMENTAL SITE

The Student's Farm is located towards South-Western side of Hyderabad at an altitude of 542.6 metres above mean Sea level with a geographical bearing of 17°19' N latitude and 78°23' E longitude.

3.2 SOIL CHARACTERISTICS

Soil samples were drawn from a depth of 0-60 cm from randomly selected spots prior to the initiation of the experiments. A homogeneous composite sample was prepared and analysed for various physical and chemical constituents of the soil. The results thus obtained are presented in Table 1.

The experimental site was red soil with sandy loam texture. The available nutrient status of the initial samples indicated that the soil had medium reserves of nitrogen and potassium, while it was rich in phosphorus. Soil reaction was weakly alkaline with a pH of 8.17.

Table 1. Physico-Chemical properties of the soil

	Particulars	Results	Method adopted
A.	Mechanical analysis		
	Soil fraction	% composition	
1.	Sand (2.0 - 0.05 mm)	46.64	International Pipette Method (Piper, 1964)
2.	Silt (0.05 - 0.02 mm)	42.00	
3.	Clay (< 0.002 mm)	11.36	
	Textural class	Sandy loam	
B.	Chemical analysis		
1.	pH	8.17 weakly alkaline	1 : 2.5 soil : water suspension (Jackson, 1967)
2.	EC mmhos cm^{-1}	0.20 Normal	Jackson (1967)
3.	Organic carbon %	0.56 Medium	Walkely and Black method (Piper, 1956)
4.	Available nitrogen kg ha^{-1}	365.00 Medium	Alkaline permanganate method (Subbaiah and Asija, 1956)
5.	Available phosphorus kg ha^{-1}	28.80 High	Olsen's method (Olsen et al., 1954)
6.	Available potassium kg ha^{-1}	166.00 Medium	Neutral normal ammonium Acetate method (Black, 1965)

3.3 WEATHER CONDITIONS

The mean meteorological data during the crop growth period for each of the three seasons are represented graphically against the standard weeks in Fig.1. The mean maximum temperatures

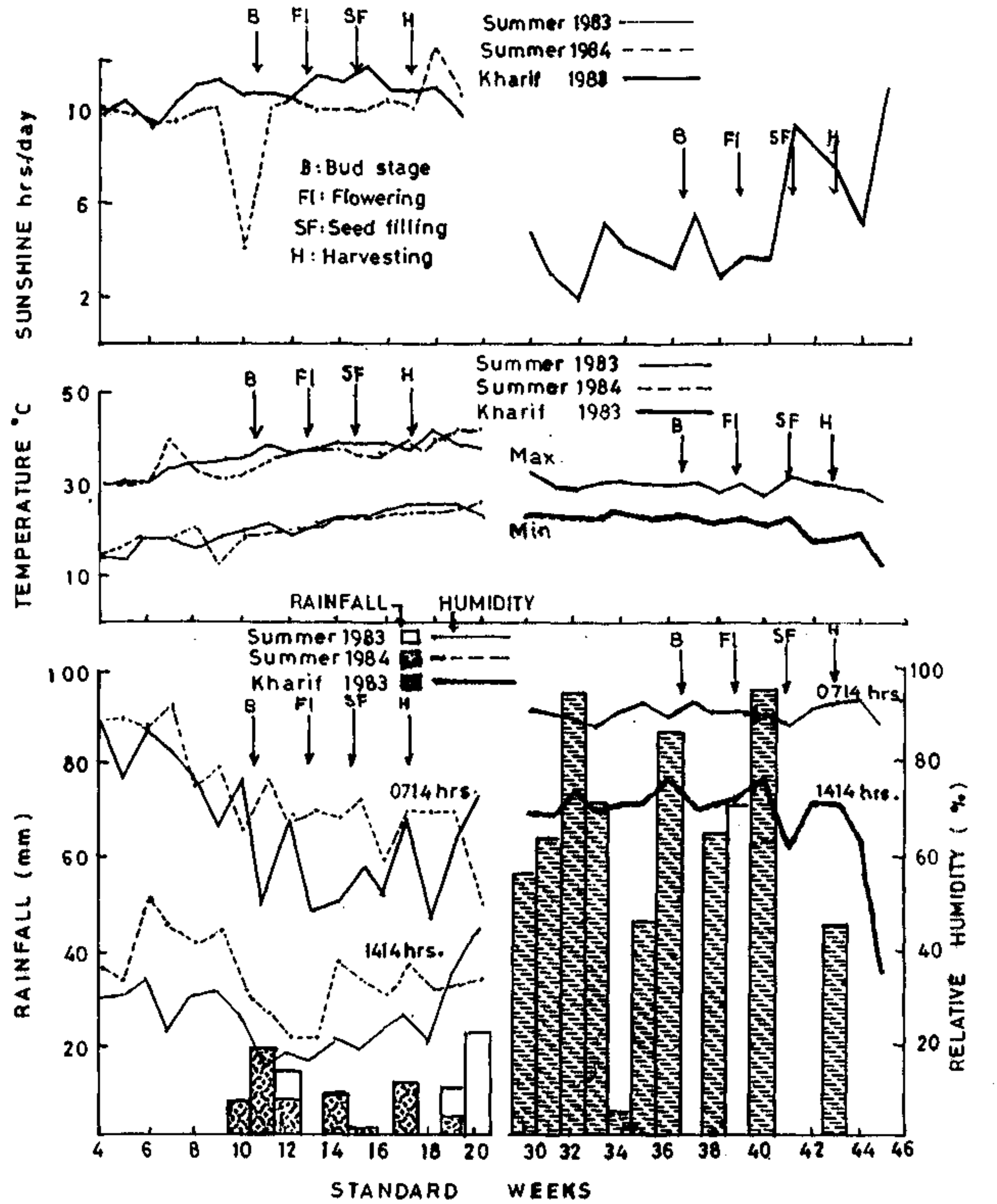


Fig:1 - WEEKLY MEAN METEOROLOGICAL DATA DURING CROP GROWTH PERIOD ranged from 28.9 to 39.3 and from 29.3 to 41.1°C during 1983 and 1984 summer seasons respectively. During *kharif* 1983 the range was from 26.1 to 31.4°C. The mean minimum temperatures during the corresponding seasons ranged from 13.5 to 25.6, from 12.6 to 25.6 and from 12.4 to 23.2°C. The mean relative humidity at 0714 hours varied from 48 to 89% and from 49 to 92% during summer, 1983 and 1984 respectively. In *kharif* the range was between 89 and 94%. The relative humidity for the corresponding seasons at 1414 hours ranged from 15 to 44, from 21 to 50 and from 36 to 77%. The hours of bright sunshine per day ranged from 4.1 to 11, from 4.5 to 11.2 and from 1.8 to 10.5. The amount of precipitation received during summer, 1983 and 1984 crop period was 48.4 and 62.9 mm respectively. The *kharif* season during 1983 was wet (740.5 mm) due to well distribution of continuous rains throughout the crop growth period.

3.4 PREVIOUS CROP HISTORY

Prior to the initiation of the present experiment, the land was sown with maize and sorghum during *rabi*, 1980 with groundnut during *kharif* 1981 and with maize during *kharif*, 1982.

3.5 EXPERIMENTAL DETAILS

Two experiments were conducted simultaneously during the three seasons. The lay-out was a systematic fan design (Fig.2) and a 3×2^2 factorial randomised block design (Fig.3) for the study of planting densities and the crop geometry respectively.

3.5.1 Systematic fan design

Sunflower was evaluated for yield density relationship over a wide range of plant populations when grown alone or intercropped with groundnut to gain a coherent understanding with the earlier reports. A systematic fan design based on the original ideas of Nelder (1962) and Bleasdale (1967) was developed for the study. Different plant populations of sunflower and groundnut were achieved by a systematic progression of row widths from the centre towards the periphery of each fan (Tables 2 and 3). The plant spacing on each spoke of the fan was held constant at 22.5 cm. Six treatments were tested in four replications. Each treatment had 26 row width variables corresponding to different plant populations.

3.5.1.1 Treatments

T_1 Sunflower with a range of narrow row widths (1.33 m at the peripheral arc)

T_2 T_1 + 2 rows of groundnut sharing 2/3 area

T_3 Groundnut replacing sunflower in T_1 + 2 rows of groundnut

T_4 Sunflower with a range of wider row widths (2.00 m at the peripheral arc)

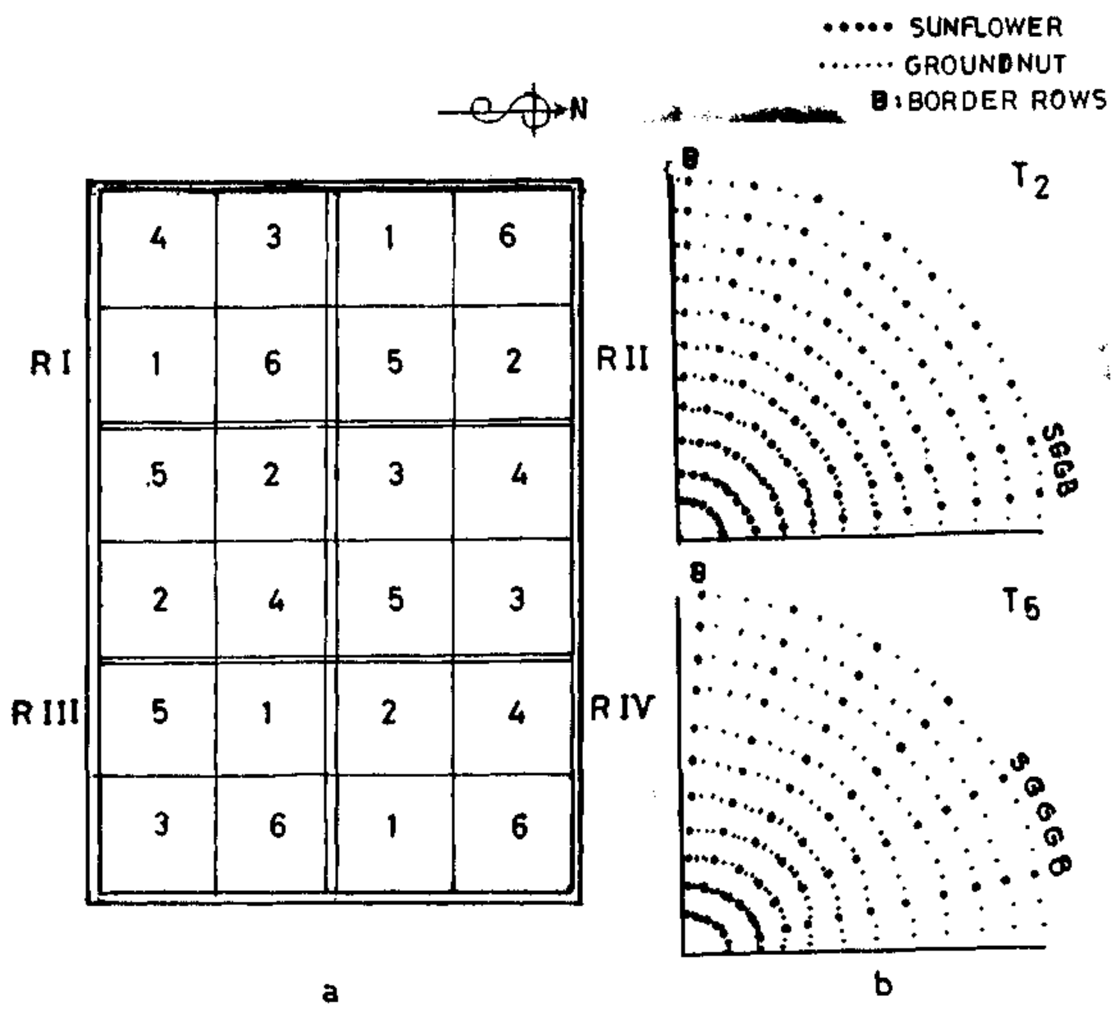
T_5 T_4 + 3 rows of groundnut sharing 3/4 area

T_6 Groundnut replacing sunflower in T_4 + 3 rows of groundnut

In order to compare the competitive ability of groundnut intercropped in sunflower, the treatments T_3 and T_6 were grown exactly in a similar manner as T_2 and T_5 except that the sunflower rows were replaced by groundnut. These rows were harvested separately and discarded. This provides a comparison of the performance of groundnut in interspecific competition in relation to its behaviour in intra-specific competition under a similar set of treatments.

3.5.1.2 Lay-out

Square plots measuring 7.65 m on each side were laid out for each treatment. A non-stretchable flexible wire 7.65 m long was fixed at one end to a peg studded at the centre of the origin of the rows of four plots. The other end of the wire was swivelled round over the circumference of the circle at required distance for sowing as per the treatments. Each fan within the quadrant of the circle with the outer arc measuring 12.02 m and an area of 45.98 m^2 constituted a treatment. The wire was swung over the arc at a distance of 1.33 m thus making 9 spokes of sunflower/replaced groundnut in narrow row width treatments. But, the wider row series were obtained by shifting the wire at every 2.0 m over the arc forming only 6 spokes in each fan. The distance between any two spokes at the point of intersection with a given arc is the row width. In intercrop system two rows of groundnut were interspersed between the spokes of sunflower/replaced groundnut in the narrow row width treatments. But, the wider row width series had three rows of groundnut interplanted between any two spokes of the main crop. There were thus eighteen spokes of intercrop in both the methods of planting. The distance of the intercrop component over the outer arc between the spokes of sunflower/ replaced groundnut was 44 cm for the narrow and 50 cm for the



Design: Systematic fan

Fig:2- a· LAYOUT PLAN OF THE SYSTEMATIC FAN DESIGN

b· SPATIAL ARRANGEMENT OF CROPS IN INTERCROP TREATMENTS T_2 AND T_5

wider row width treatments respectively. The plant spacing on each spoke of the intercrop was 22.5 cm as that of sunflower irrespective of the treatments. This was intended to facilitate the identification of arcs. Intercrop component formed a planting density that would share 2/3 proportion of the nutritional area at any given density of sunflower over the range in narrow row width treatments. While this constituted 3/4 nutritional area in the wider row series.

3.5.1.3 Parameter estimates and statistical analysis

Planting density per hectare was calculated for the corresponding row width at each arc from the estimated area per plant. The calculations for length of the arc, area of the sector, row width, area per plant and the planting density per hectare (Tables 2 and 3) were performed by the following relationships.

1. **Length of the arc:** The length of any given arc in the fan is the distance between two radii of the sector at the point of intersection with the corresponding arc

$$LA = \frac{d^\circ}{360} \times 2\,\pi r$$

Where,

LA = Length of the arc

d = angle of the sector

π = 22/7 or 3.1416

r = radius of the sector at the intersection of corresponding arc.

2. **Area of the sector:** The area of the sector is the area of each fan forming quarter of a circle with desired radius.

Table 2. Row width, area per plant and planting density per hectare of sunflower in narrow and wider row treatments

Arc No.	Narrow row width treatments			Wider row width treatments		
	RWns (cm)	An (cm^2)	PDn ha^{-1}	RWns (cm)	An (cm^2)	PDn ha^{-1}
1.	125.66	2819.51	35467	188.50	4234.36	23616
2.	121.73	2731.40	36611	182.60	4102.04	24738
3.	117.81	2650.93	37722	176.71	3969.72	25190
4.	113.88	2555.18	39136	170.82	3837.39	26059
5.	109.95	2467.07	40533	164.93	3705.06	26990
6.	106.03	2378.96	42035	159.04	3572.74	27989
7.	102.10	2290.85	43652	153.15	3440.42	29066
8.	98.17	2202.75	45397	147.26	3308.09	30228
9.	94.25	2114.64	47289	141.37	3175.77	31488
10.	90.23	2026.52	49345	135.35	3043.45	32857
11.	86.39	1938.42	51588	129.59	2911.12	34351
12.	82.47	1850.30	54045	123.70	2778.80	35986
13.	78.54	1762.19	56747	117.81	2650.93	37722
14.	74.61	1674.08	59734	111.92	2514.15	39774
15.	70.68	1585.97	63052	106.03	2381.83	41984
16.	66.76	1497.87	66761	100.14	2249.50	44454
17.	62.83	1409.75	70934	94.25	2117.18	47232
18.	58.90	1321.65	75662	88.36	1984.85	50381
19.	54.98	1233.54	81067	82.47	1852.53	53980
20.	51.05	1145.43	87303	76.58	1720.21	58132
21.	47.12	1057.32	94578	70.69	1587.88	62977
22.	43.20	969.21	103176	64.79	1455.56	68702
23.	39.27	881.09	113495	58.90	1323.24	75572
24.	35.34	792.99	126104	53.01	1190.91	83969
25.	31.42	704.88	141868	47.12	1058.59	94465
26.	27.48	616.77	162134	41.22	926.27	107959

RWns (cm) = Row width of sunflower at n^{th} arc in centimetres

An (cm^2) = Apparent area per plant at n^{th} arc in square centimetres

PDn ha^{-1} = Planting density per hectare

Table 3. Row width in the narrow and wider row treatments, apparent area per plant, planting density per hectare and virtual area per plant of groundnut

Arc No.	RWng (cm) Narrow row treatment	RWng (cm) Wider row treatment	An (cm^2)	PDn ha^{-1}	VAn (cm^2) Narrow row treatment	VAn (cm^2) Wider row treatment
1.	41.89	47.12	1413.71	70735	942.48	1060.28
2.	40.58	45.65	1369.65	73011	913.02	1027.15
3.	39.27	44.18	1325.45	75446	883.57	994.02
4.	37.96	42.71	1281.28	78046	854.12	960.88
5.	36.65	41.23	1237.10	80834	824.67	927.75
6.	35.34	39.76	1192.92	83827	795.21	894.62
7.	34.03	38.29	1148.74	87051	765.76	861.48
8.	32.72	36.82	1104.55	90534	736.31	828.35
9.	31.42	35.34	1060.36	94307	706.86	795.21
10.	30.08	33.84	1016.19	98406	677.40	762.08
11.	28.80	32.40	972.00	102880	647.95	728.95
12.	27.49	30.92	927.82	107779	618.50	695.81
13.	26.18	29.45	883.64	113168	589.05	662.68
14.	24.87	27.98	839.46	119124	559.60	629.55
15.	23.56	26.51	795.28	125741	530.14	596.41
16.	22.25	25.03	751.09	133139	500.69	563.28
17.	20.94	23.56	706.91	141460	471.24	530.14
18.	19.63	22.09	662.72	150893	441.79	497.00
19.	18.33	20.62	618.55	161668	412.33	463.87
20.	17.02	19.14	574.36	174106	382.88	430.74
21.	15.71	17.67	530.18	188615	353.43	397.61
22.	14.40	16.20	486.00	205761	323.98	364.47
23.	13.09	14.73	441.82	226336	294.52	331.34
24.	11.78	13.25	397.64	251483	265.07	298.20
25.	10.47	11.78	353.46	282917	235.62	265.07
26.	9.16	10.30	309.24	323362	206.17	231.94

RWng (cm) = Row width of groundnut between sunflower radii at n^{th} arc

An (cm^2) = Apparent area per plant at n^{th} arc in square centimetres

PDn ha^{-1} = Planting density per hectare

VAn (cm^2) = Virtual area per plant at n^{th} arc in square centimetres

$$AS = \frac{lr}{2} \text{ or } \frac{d^\circ}{360} \times \pi r^2$$

Where,

AS = Area of the sector

l = length of the arc

r = radius

d = angle of the sector

¶ = 22/7 or 3.1416

3. Row width : Row width is the distance between the plants at the points of intersection of any two adjacent spokes on an n^{th} arc for a given treatment.

a. Sunflower

$$RWns = \frac{2 \pi rn}{N}$$

Where,

RWns = Row width of sunflower at n^{th} arc

¶ = 22/7 or 3.1416

rn = Radius at n^{th} arc

N = Number of radii or spokes in the circle or number of radii in the fan X 4

b. Groundnut

$$RWng = \frac{RWns}{Sg+1}$$

Where,

RWng = Row width of groundnut between sunflower radii at n^{th} arc

RWns = Row width of sunflower at n^{th} arc

Sg+1 = Number of spokes of groundnut within the row width of sunflower at n^{th} arc + 1.

4. Area per plant : The area per plant is the size of area available to an individual plant in a crop community over unit area of land and the given planting density *per se*.

a. Apparent area : The apparent area was considered as the area per plant actually occupied by a given crop irrespective of the area shared if any by the companion growth of the other species in the intercrop system.

$$An = [\pi r^2_{nmi} - \pi r^2_{nmj}] \times \frac{1}{N}$$

Where,

An = Apparent area per plant at n^{th} arc

r_{nmi} = Radius at mid-point between the n^{th} and next adjacent arc

r_{nmj} = Radius at mid-point between the n^{th} and previous adjacent arc

N = Number of radii or spokes of the crop in question in the circle

b. Virtual area : Virtual area per plant of any one species in the intercrop system was regarded as the area per plant in effect though not in fact, irrespective of the optimum requirement.

$$VAn = [\pi r^2_{nmi} - \pi r^2_{nmj}] \times \frac{1}{Nsg}$$

Where,

VAn = Virtual area per plant at n^{th} arc

$\frac{1}{Nsg}$ = Number of spokes or radii of both the species (sunflower and groundnut) in the circle.

c. **Per cent shared area** : Refers to the imposed virtual area of the intercrop as per cent of the apparent area of the main crop.

$$SA = \frac{VAn}{An} \times 100$$

Where,

SA = Per cent shared area

VAn = Virtual area at n^{th} arc

An = Apparent area at the corresponding n^{th} arc

5. **Planting density** : Planting density refers to the plant population per unit area.

$$PDn = \frac{PA}{An}$$

Where,

PDn = Planting density per unit area

PA = Desired unit area to be planted

An = Apparent area per plant at n^{th} arc.

For statistical scrutiny, the data on seed/pod and oil yield per plant were regressed on the planting density for each treatment. To establish the best fit, transformations of planting densities and yield or yield alone into common and natural logs were attempted. Natural log transformations of the yield data improved the curves giving the best fit both for sunflower and groundnut. But, transformation of total oilseeds or oil yield data in intercrop system did not improve the efficiency, and hence, only the absolute data was regressed on the planting density.

The yield-density relationship each of sunflower and groundnut was established by the modelling approach developed by Liu Li et al. (1984) as shown below :

$$y = a\ exp(bx)(b < o) \quad \text{---------- } 1$$

$$Y = ae\ exp(bx)(b < o) \quad \text{---------- } 2$$

$$x_{opt} = -1/b\ (b < o) \quad \text{---------- } 3$$

$$y_{x.opt} = a/e \quad \text{---------- } 4$$

$$Y_{max} = x_{opt}\ a/e \quad \text{---------- } 5$$

Where,

y	=	Yield per plant
x	=	Plant population
exp(bx)	=	Exponential function of bx
Y	=	Yield per unit area
x_{opt}	=	Optimum plant population
$Y_{x.opt}$	=	Yield per plant from the optimum plant population
Y_{max}	=	Maximum yield from the optimum plant population and
a, b	=	Coefficients of the models

The biological meaning of the coefficients a and b is that 'a' represents the maximum yield that an average plant in a non-competetive colony of sunflower may approach; and 'b' stands for, when the plant population increases one unit, the unit number of the natural logarithm of the plant number which needs to increase when one unit yield per unit area is produced, and also the average nutritive area a plant requires for the maximum yield per unit area. Comparison of regression lines between the treatments were performed as per the procedures outlined by Roy et al. (1959) and Steel and Torrie (1982). Tests were made for the identity of the regression equations (F_1), equality of the intercepts (F_2) and Parallelism of the slopes (F_3). Pooled analysis of the regression equations were performed between the sets of treatments if the hypothesis proved that the regression lines are identical.

3.5.2 Randomised block design

The crop geometry studies of sunflower with a constant plant population of 74×10^3 plants ha^{-1} both in sole and intercrop situation were taken up in a factorial randomized block design. Three factors of planting sunflower, viz.,planting system, method and pattern were evaluated each at two levels, i.e., sole Vs intercrop, narrow Vs wider rows and equidistant Vs paired row pattern respectively. There were twelve treatments in three replications. The plot size was 9.0 x 5.4 m. Intercrop system was formulated in an additive model with 100% intensity each of sunflower and groundnut as in the sole crops. The population of groundnut was 333×10^3 plants ha^{-1} both in sole and intercrop situation.

3.5.2.1 Treatments

T_1	Sunflower at 60 x 22.5 cm
T_2	Sunflower at 60 x 22.5 cm + 2 rows of groundnut
T_3	Groundnut replacing sunflower + 2 rows of groundnut
T_4	Sunflower at 90 x 15 cm
T_5	Sunflower at 90 x 15 cm + 3 rows of groundnut

T_6	Groundnut replacing sunflower + 3 rows of groundnut
T_7	Sunflower at 40 - 80 x 22.5 cm
T_8	Sunflower at 40 - 80 x 22.5 cm + 2 rows of groundnut
T_9	Groundnut replacing sunflower + 2 rows of groundnut
T_{10}	Sunflower at 60 - 120 x 15 cm
T_{11}	Sunflower at 60-120 x 15 cm + 3 rows of groundnut
T_{12}	Groundnut replacing sunflower + 3 rows of groundnut

3.5.2.2 Lay-out

Sunflower rows were uniformly spaced 60 and 90 cm apart for the narrow and wider row width treatments respectively. In paired pattern the corresponding row spacings were increased to 80 and 120 cm between the pairs while keeping a distance of 40 and 60 cm between the rows of each pair. Two rows of groundnut were intercropped in the narrow row widths and three rows in the wider row spacings of sunflower both in the equidistant and paired row pattern. To achieve the optimum population of intercrop as in the sole stand, the groundnut rows were spaced 20 and 22.5 cm apart between the rows of sunflower in the equidistant-narrow and wider row widths respectively. Plant spacing within the rows was 10 cm. In paired pattern the density was maintained by arranging the intercrop rows at a respective distance of 26.6 and 30 cm in the spacing between the two pairs of sunflower. Plant spacing within the rows was 5 cm (Fig.3).

The performance of groundnut in interspecific competition (intercrop system) was compared with the corresponding sole crop of each treatment in an intra-specific competition. The sole crop was raised in exactly the same manner as in

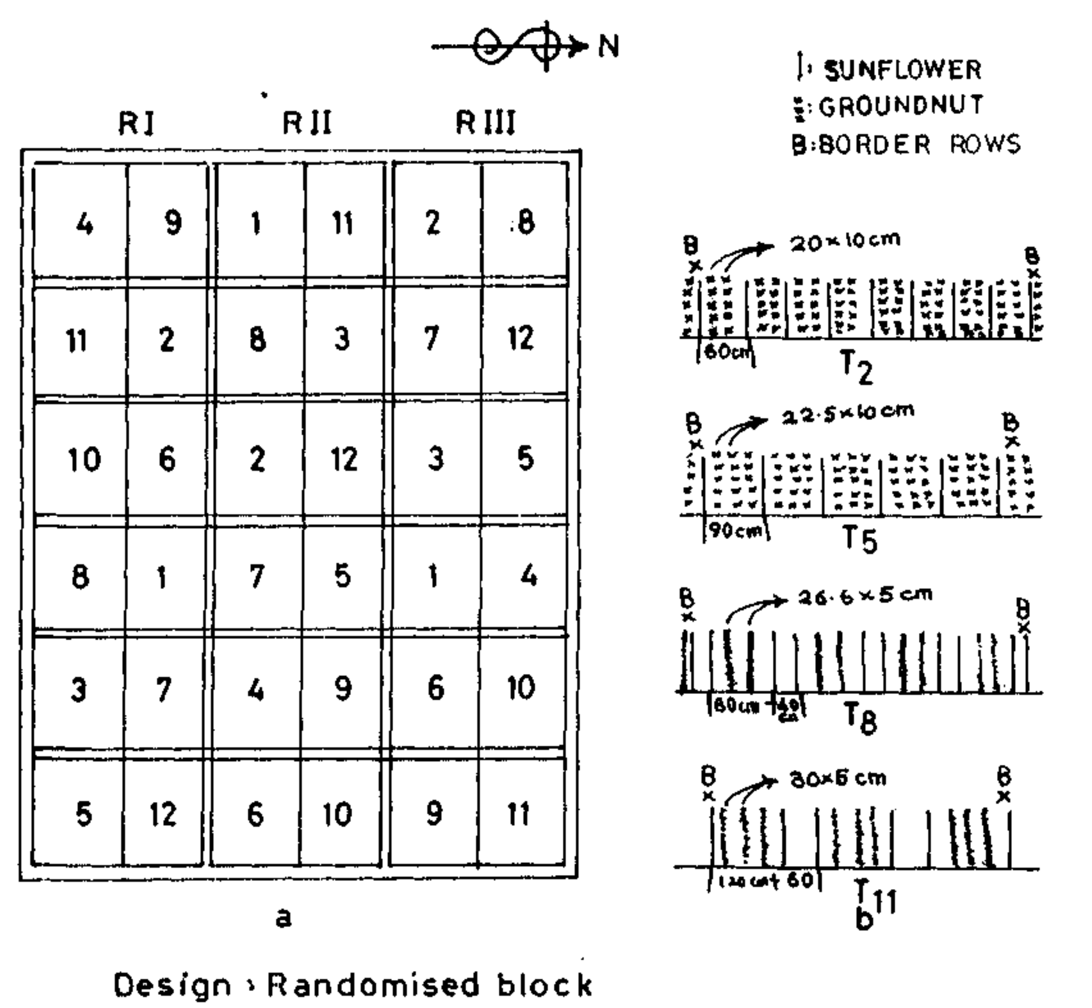


Fig:3- a. LAYOUT PLAN OF THE RANDOMISED BLOCK DESIGN

b. SPATIAL ARRANGEMENT OF CROPS IN INTERCROP TREATMENTS T_2, T_5, T_8 AND T_{11}

intercrop treatments but was flanked with groundnut replacing the rows of sunflower. The fertilizer schedule was essentially the same as in intercrop system so as to enable the relative quantification of competitive effects under similar set of situations.

3.6 DETAILS OF FIELD OPERATIONS

All the requisite operations detailed below (Table 4) were common for both the experiments.

Table 4 ·: Calender of operations

S. No.		Operation	Date		
			Summer 1983	Kharif 1983	Summer 1984
1.	Preparatory cultivation				
	a.	Ploughing	4-1-83	26-6-83	8-1-84
	b.	Tillering	13-1-83	12-7-83	15-1-84
	C.	Harrowing	14-1-83	13-7-83	16-1-84
	d.	Levelling	15-1-83	15-7-83	17-1-84
	e.	Lay out	16-1-83	18-7-83	19-1-84
	f.	Levelling of individual treatment plots	17-20 January 1983	19-20 July 1983	20-23 January 1984
2.	Fertilizer application				
	a.	Basal	21-1-83	21-7-83	24-1-84
	b.	Top dressing	5-3-83	6-9-83	10-3-84
3.	Seeds and sowing				
	a.	Sowing	21-1-83	21-7-83	24-1-84
	b.	Thinning	8-2-83	5-8-83	10-2-84

S. No.	Operation	Date Summer 1983	Kharif 1983	Summer 1984
4.	Weeding			
	Hand weeding	26-2-83	14-8-83	28-2-84
		17-3-83	20-9-83	12-3-84
5.	Irrigations	Jan,22 and 31 Feb.7, 13 and 25 March 6, 14 and 22 April 8 and 16 May 6 and 20	Nil	Jan.26 Feb.29 March 10, 17, 24 and 31 April 17 and 23 May 2 and 6
6.	Plant protection			
	a. Spraying Monocrotophos	27-2-83	17-8-83	6-4-84
	b. Spraying Rogor	12-3-83	9-10-83	4-3-84
		5-3-83	-	-
	c. Spraying Metasystox	-	30-8-83	-
	d. BHC Dust 10%	-	21-10-83	-
7.	Harvesting			
	a. Sunflower	21-4-83	20-10-83	23-4-84
	b. Groundnut	21-5-83	3-11-83	8-5-84

3.6.1 Preparatory cultivation

The field was ploughed with tractor drawn disc plough followed by tillering and harrowing in each season. The plot was then levelled with cattle drawn levelling plank. The lay-out for each experiment was taken up as per the plan and plots for different treatments were demarcated with the bund former. The individual plots were then perfectly levelled manually with wooden rakes.

3.6.2 **Fertilizers and fertilizer application**

Fertilizers were applied to the crop components at the rates indicated in Table 5.

Table 5 . Rate of fertilizer application to different treatments

Crop/treatments	Fertilizers kg ha^{-1}		
	N	P_2O_5	K_2O
Sunflower	60	40	40
Groundnut	Rhizobium	40	40
Intercrop system (sunflower + groundnut or replaced groundnut + groundnut)	60 to sunflower/ replaced groundnut and rhizobium inoculation to intercropped groundnut	40 + 40	40 + 40

Nitrogen in the form of urea was applied in two splits along the rows of sunflower. One third nitrogen (20 kg ha^{-1}) was applied at the time of sowing and rest (40 kg ha^{-1}) 45 days later. Groundnut was inoculated with the rhizobium strain 'NC 92' obtained from ICRISAT because its compatibility with the cultivar 'Kadiri-3', had been specifically reported to be very strong (Nambiar and Dart, 1982). However, groundnut replacing the rows of sunflower was treated in exactly the same manner as the latter. In other words it was fertilized with 60 kg N ha^{-1} in two splits as in sunflower.

The scheduled quantities each of phosphorus and potassium in the form of super phosphate and muriate of potash were broadcast in the treatmental plots at the time of sowing. In intercrop system each crop component was treated with the same fertilizer dose as in the respective sole crops. Therefore, the system received the total quantity of phosphorus and potassium required for sunflower and groundnut in the sole crops.

3.6.3 Seeds and sowing

In the summer seasons seeds of sunflower and groundnut were sown on 21 and 24, January during 1983 and 1984 respectively. In kharif sowings were taken up on 21 July, 1983. Seeds were sown at the required spacings as per the treatments. Sunflower commenced germination within 4 - 5 days after seeding during the three seasons. Emergence in groundnut commenced 15 days after sowing during summer, 1983. But during the subsequent kharif and summer the crop emerged within a week of sowing. Germination percentage of both the crops was satisfactory in the three seasons (Appendix-I). Plants were thinned to one seedling per hill after about a fortnight of sowing.

The test cultivars of sunflower and groundnut were 'Peredovik' (EC 68414) and 'Kadiri-3' (Robut 33-1) respectively. Among the introduced Russian cultivars 'Peredovik' is the most promising and is predominantly adopted in different parts of the country particularly in Andhra Pradesh. It has a high potential both for seed and oil yield compared to other cultivars. The crop matures in about 90 days.

The cultivar 'Kadiri-3' is an early maturing (105-110 days) virginia runner type of groundnut evolved by pure line selection at the Andhra Pradesh Agricultural University. This was released by the Andhra Pradesh State Variety Release Committee in 1978. Its cultivation is adopted to the entire groundnut growing areas of the country and can be grown both in kharif and summer seasons. It has a strikingly smaller plant size with a clustered bearing of pods closer to the root zone and has a higher yield potential (Reddy et al., 1980).

3.6.4 Weeding

Hand weeding was taken up during the fifth week after sowing in the summer seasons and in the fourth week during kharif. A second weeding was inevitable for the sole crop of groundnut as the weed infestation was too high particularly with the Cyperus and Cynodon species dominating the forage. Hand weeding was therefore taken up again with meticulous care to have least disturbance to the pegs penetrating the soil about three weeks later in the summer seasons and five weeks after the first weeding in kharif. Sunflower had practically smothered the weed flora to a large extent both in sole and intercrop situations. Yet weeding was taken up in these treatments too, to have a similarity of operations with the other treatments.

3.6.5 Irrigation

The crops were irrigated uniformly as and when required during the summer seasons. In kharif, the crops were grown rainfed.

3.6.6 Plant protection

Sunflower was free from pests or the diseases that would cause an economic threat to the crop. A mild incidence of basal stem rot incited by *Sclerotinia sclerotiorum* (Lib.) de Bary, was observed only during the *kharif* season. The incidence of leaf miner (*Aproaerema modicella* Dev.) in groundnut was rampant in the summer seasons and to a lesser extent in *kharif*. Spraying with systemic insecticides, viz., Monocrotophos, Rogor or Metasystox @ 0.05% concentration was taken up as per the schedule indicated in Table 4 to manage the pest menace. Late in the growing season the *kharif* crop in randomised block design was heavily infested with the pod boring insect larvae, the wireworms (*Diabrotica* sp.). Peculiarly groundnut intercropped with sunflower was completely free from the pest ravage. The adjacent systematic design also showed only a minor incidence. BHC 10% @ 20 kg ha^{-1} was incorporated into the soil along the rows of groundnut when the incidence was recorded at the sampling stage (90 days) prior to harvest so as to save the crop from further damage.

3.6.7 Bird scaring

Labour were employed to ward-off the crows (*Corvus splendens* Vieillot) with a flail from sowing till complete emergence of groundnut and to scare-off the rose ringed parakeets (*Psittacula krameri* Scopoli) from seed filling till harvest of the sunflower crop.

3.6.8 Harvesting

The crops were harvested at the physiological maturity. Sunflower was harvested 90 days after sowing in the three seasons. While groundnut was harvested at 120 days during summer 1983 and at 105 days during *kharif* 1983 and summer 1984.

In the systematic design two arcs at the periphery of each treatment and one spoke of sunflower/replaced groundnut on either side of the fan was harvested as border material. A series of 26 successive arcs in each treatment were harvested separately for sunflower and groundnut. Mean yield per plant was worked out for each corresponding arc. Rest of the arcs towards the centre were discarded due to overcrowding of plants.

In randomised block design one row of sunflower/replaced groundnut alongwith the rows of intercrop if any and two hills on either side of the rows were eliminated as border material.

In treatments with intra-specific competition, the replaced groundnut rows were harvested separately and discarded.

3.6.9 Threshing/stripping

The harvested sunflower heads were sundried and the produce for each treatment was threshed manually with the sticks. The seeds were then cleaned by winnowing and the produce of dry weight recorded. Pods from groundnut plants were stripped-off immediately after pulling with the help of iron stripper. Pods from each treatment were dried under shade and then the weights were recorded after complete drying.

3.7 SAMPLING TECHNIQUES

Observations on the morpho-physiological parameters of sunflower and groundnut were recorded as means of the five competitive plants sampled at random from each treatment in the randomised block design. The first sampling was initiated on 30 days of sowing and continued thereafter at fortnightly intervals till harvest of each crop. Studies on neutro-periodism were also made from the sampled material at each successive stage of sampling. The techniques adopted for gathering the data are enumerated for each parameter.

3.7.1 Plant height (cm)

Plant height was measured with a linear meter scale in centimetres. In sunflower, plant height was measured from base of the stem upto the apical meristem during the vegetative phase and upto the base of the receptacle on the peduncle during the reproductive phase.

In groundnut the main axis was measured for its elongation with crop age from ground level upto the apical meristem throughout the samplings.

3.7.2 Number of leaves per plant

The total number of fully expanded active leaves per plant each of sunflower and groundnut were recorded at different growth stages.

3.7.3 Leaf area per plant (cm^2)

Leaf area was measured over an automatic electronic digital leaf area meter (LI-3100, Area meter, USA). At each sampling leaves from the five plants were separated and immediately inserted into the flaps of the conveyer belt while they were still turgid. The area was recorded as mean per plant each for sunflower and groundnut separately.

3.7.4 Number of branches per plant

The number of primary branches per plant of groundnut were counted on the sampled plants at all the sampling instances.

3.7.5 Phytomass accumulation (g)

The sunflower plants were partitioned into leaves and stem during the vegetative phase and further into heads during the reproductive phase. Again at harvest the seeds were separated from the discs of the capitulum. Similarly the groundnut' leaves were separated from the stem and with the development of the reproductive sink the pods were removed separately. The material was dried in a forced hot air oven at 70°C for 48 hours after constant drying in the sun. Components of each plant part were then weighed on an electronic precision balance and the weights recorded in grams.

3.7.6 Number of pegs per plant

The number of gynophores or the pegs per plant were recorded on the sampled plants of groundnut at periodical samplings.

3.7.7 Number of pods per plant

The carpophores in groundnut were accounted as pods when the tips of gynophores penetrating the soil had bulged to the size of a pea. The number of pods produced per plant were counted at each stage of development.

3.7.8 Diameter of Capitulum (cm)

Diameter of the capitulum was measured in centimetres with a flexible linear scale across the central position from one peripheral part of the circumference to the other at the time of harvest of sunflower.

3.7.9 Number of seeds per plant

The number of seeds developed on the receptacle of each capitulum in sunflower were counted after separating the seeds manually at harvest.

3.7.10 Test weight (g)

Thousand seeds of sunflower and hundred pods of groundnut were counted from the net produce of each treatment in each replication and the weights were recorded in grams.

3.7.11 Shelling per cent

A sample of 500 g of groundnut pods was drawn from each treatment from all the replications. The pods were then shelled and the weight of kernels recorded. Shelling per cent was calculated as the ratio of kernel weight to that of pods expressed in per cent.

3.7.12 Oil per cent

Oil per cent of sunflower seeds and groundnut kernels was estimated for each plant sample at harvest over the nuclear magnetic resonance spectrometer (Minispec P_{20i}).

Oil estimation from seed of sunflower and kernel of groundnut samples was also done for each planting density in the systematic design. A composite sample was drawn from the harvested produce of each arc representing the planting density from each treatment in all the replications.

3.7.13 Oil yield (kg ha^{-1})

Oil yield was worked out as the product of per cent oil and weight of the corresponding produce (seed/kernel) obtained per unit area on dry weight basis.

3.7.14 Yield (kg ha^{-1})

Seed yield of sunflower and pod as well as the haulm yield of groundnut obtained from the net plots were worked out for per hectare estimates in kilograms.

3.7.15 Chemical analysis

The major nutrient composition of each plant part of both the crop species was estimated throughout the samplings. The samples for dry matter studies were ground in an electric grinder and the material passed through a 20-mesh screen was collected for chemical analysis. The estimation of nitrogen, phosphorus and potassium was carried out following the procedure outlined by Judith and Webb (1970).

The nutrient uptake was worked out as the product of per cent nutrient element and the dry weight of the corresponding plant part.

3.8 ECONOMICS

The economics of planting systems were evaluated in terms of gross and net returns per hectare as well as the net profit per rupee investment.

3.8.1 Gross returns (Rs ha^{-1})

The prevailing market prices of each crop component at the time of harvest were considered for the monetary values of the produce obtained from each treatment. The market prices both of sunflower seed and groundnut pods at the Agricultural market committee, Osman Gunj, Hyderabad, were fluctuating around Rs 400 q^{-1}. Therefore, the mean rate of Rs 400 q^{-1} was considered for both the crops in the present investigation. The cost of groundnut haulms was fixed at Rs 10 q^{-1}.

3.8.2 Net returns (Rs ha^{-1})

The net returns were worked out after deducting the operational cost, input expenditure, the rental value of land and other items (Appendix II) from the gross emoluments per hectare as outlined in the case studies for sunflower and groundnut by Changule and Kalyankar (1983) and Reddy (1982) respectively.

3.8.3 Net return per rupee investment (Rs)

The net profit per rupee investment for different treatments was worked out as the quotient of total cost of cultivation over the net profit per hectare for a given treatment.

3.8.4 Relative net returns

The RNR index proposed for any intercropping system to be compared with the major sole crop was worked out following the approach suggested by Jain and Rao (1980) as

$$\textbf{RNR} = \frac{(Pi\ Yi + Pj\ Yj) \pm Dij}{Pi\ Yii}$$

Where,

RNR = the relative net returns

Yi and Yj = the yields of i-th major crop per hectare and j-th intercrop per hectare in i, j-th crop combination

Pi and Pj = the prices of i-th major crop and j-th intercrop respectively.

Yij = the yield of i-th sole crop per hectare and

Dij = the differential cost of cultivation of i, j-th crop combination in comparison to i-th sole crop

3.9 COMPETITIVE INDICES

Although several competitive indices have been proposed from time to time for evaluating the crop productivity in an intercrop system only the current and more relevant indices have been adopted for the present studies.

3.9.1 Land equivalent ratio (LER)

Land equivalent ratio (LER) is an index most commonly used in intercropping research and is defined as the total land area of sole crops required to achieve the same yield as in the intercrops (Willey, 1979). It is formally expressed as

$$\textbf{LER} = (Y_{ij} / Y_{ii}) + (Y_{ji} / Y_{jj}) \text{ or } L_i + L_j$$

Where,

LER = Land equivalent ratio

Y = the yield per hectare,

ii and jj = pure stands of species I and J,

ij and ji = intercrops

The partial land equivalent ratios (PLER); L_i and L_j represent the ratios of yield of crops I and J when grown as intercrops, relative to their yields in pure stands. Thus

$$L_i = Y_{ij} / Y_{ii} \quad \text{and} \quad L_j = Y_{ji} / Y_{jj}$$

LER is the sum of two partial land equivalent ratios so that LER = $L_i + L_j$.

3.9.2 Staple land equivalent ratio (SLER)

Reddy and Chetty (1984) defined the staple land equivalent ratio (SLER) for a crop in terms of the ratio of the required yield to the sole crop yield per unit area with standardization by the corresponding sole crop yields, i.e., from sole crops grown under the same conditions as the intercrop. The added advantage over LER is that the SLER values can be represented graphically.

The diagram of SLER values plotted against the standardized yields of sole crop Y_{ii} in various treatments indicate that the three vertices of the triangle represent the standardized yield values when the entire area is planted to the sole crop Y_{ii}, sole crop Y_{jj} and intercropping Y_{ij} respectively.

3.10 CALORIFIC EQUIVALENT

The calorific equivalent of the oilseed crops in intercrop system as well as those of individual components in the sole crop were worked out on the basis of the reported values of 567 Kcal 100 g^{-1} of groundnut pods and 627 Kcal 100 g^{-1} of sunflower seeds (Gopalan et al., 1980). The results are presented as million kilo calories per hectare (m Kcal ha^{-1}).

3.11 STATISTICAL ANALYSIS

Statistical evaluations of sunflower and groundnut were made separately for each crop in a 2^3 factorial arrangement. The treatment effects were partitioned into single degrees of freedom as per the procedure outlined by Snedecor and Cochran (1967). To evaluate the total productivity of oilseeds and oil per hectare, their economics and the LERS due to planting systems, the analysis was performed in a 3×2^2 factorial arrangement. Pooled analysis over seasons for yield was attempted wherever the Bartlett's test of homogeneity showed no significant differences in the error variances.

The yield data from intercrop treatments were also compared simultaneously by a bivariate analysis of variance as suggested by Pearce and Gilliver (1978). The yield both of sunflower and groundnut in sole and intercrop system were transformed and plotted on the skew axes (z_1 and z_2), the angle θ being such that its cosine is the correlation coefficient of the yield data between x_1 and x_2.

$$\cos \theta = V_{12}/\sqrt{V_{11}V_{22}}$$

The transformation of yield data into Z_1 values for sunflower and Z_2 for groundnut were performed as follows

$$z_1 = x_1/\sqrt{V'_{11}}$$

$$z_2 = x_2/\sqrt{V'_{22}}$$

Where,

$$V'_{11} = V_{11} - V_{12} / V_{22},$$

$$V'_{22} = V_{22} - V_{12} / V_{11}$$

The variates V_{11} and V_{22} are the error variances and V_{12} the error covariance when analysed and V'_{11} and V'_{22} are the variances after adjusting each variate by the other.

The significance of the treatment effects was judged by calculating $d^2 = 2\ (T_{11} + T_{22})/n$, which if exceeds $\frac{4e\ FC}{n(e-1)}$ would be significant and this has been shown by drawing a circle around the mean intercrop treatment point in the diagram.

FC = Critical value of F for 2 and (e-1) degrees of freedom at the significance level required.

e = Error degrees of freedom and

n = Number of observations

T_{11} or T_{22} was worked out as $1/2\ n\ (y_1)^2$ or $1/2\ n\ (Y_2)^2$.

CHAPTER IV

RESULTS

CHAPTER IV

RESULTS

Data generated on the morpho-physiological characteristics and neutro-periodism of the plant components as a function of time under varying crop geometry of sunflower sown as a sole crop or intercropped with groundnut are presented in this chapter with relevant interpretation. The total productivity from intercropping system, their economics, competitive studies determining the productivity and the calorific values of the system are also dealt.

Results obtained from plots of data regressed on density from a concomitant trial to evaluate the yield-density relationship of sunflower sown as a sole crop or intercropped with groundnut are also collected for different treatments.

CROP GEOMETRY STUDIES

Sunflower and groundnut were evaluated individually for their relative performance under different treatments and also for their combined effect in intercrop system in relation to the sole crops.

4.1 SUNFLOWER

4.1.1 Morpho-physiological characteristics

4.1.1.1 Plant height (cm)

Plant height of sunflower as influenced by different treatments at varying phenological stages and the corresponding errors of the estimate are presented in Fig.4. The treatmental effects were not found to be significant.

The mean plant height increased from 25.32 and 31.38 cm in the vegetative phase (30 days) to 142.93 and 148.73 cm at flowering (60 days) during summer 1983 and 1984 respectively. In kharif the increase was from 20.81 to 111.58 cm. Plants further increased in height at a very slow rate and attained the maximum (148.31 and 152.43 cm in the summer seasons and 122.28 cm in kharif) at maturity.

Planting system significantly influenced the height of sole crop only at the bud formation phase (45 days) during summer 1984 and at bud (45 days) and flowering (60 days) stages of the crop during kharif 1983.

The changed row spacing did not show a striking difference in plant height at most samplings. Plants in general grew marginally taller in the narrow row spaces but did not differ significantly in either of the summer seasons except at bud stage during summer 1984. While in kharif significantly taller plants were observed in wider rows at bud and seed filling stages.

The pattern of row arrangement seemed to have no marked influence on the plant height. Equidistant or the paired row configurations were equally effective in producing plants that were not statistically dissimilar in height at any stage.

The interactions were not significant except between planting system and method at vegetative stage in summer and at maturity in kharif during 1983 and between planting system and pattern at bud stage during summer 1984.

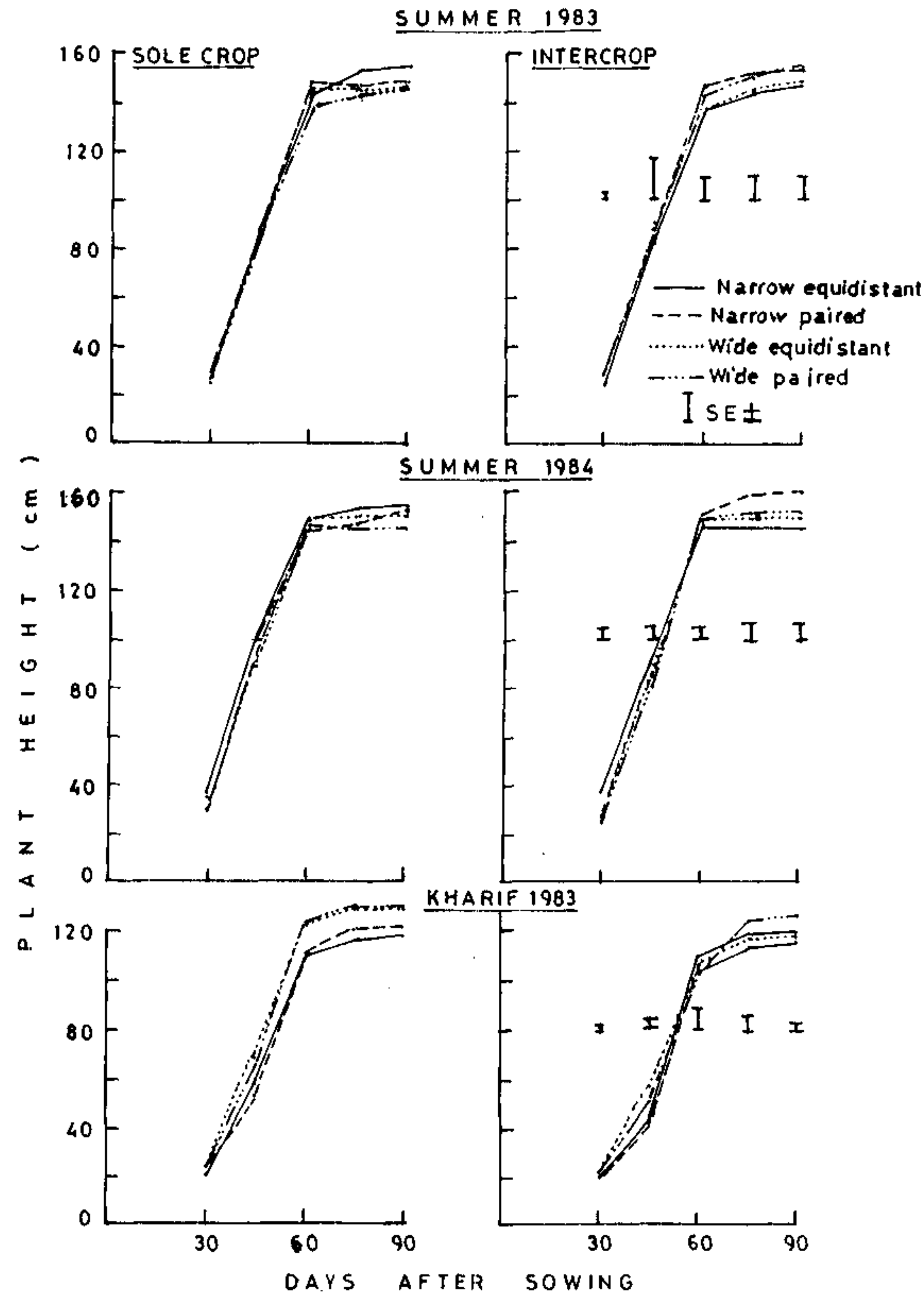


Fig:4 - PLANT HEIGHT OF SUNFLOWER AS INFLUENCED BY PLANTING GEOMETRY IN SOLE AND INTERCROPPING SYSTEM

4.1.1.2 Number of leaves per plant

Number of functional leaves per plant as influenced by different treatments were not significant (Fig.5).

The mean number of leaves per plant increased at a faster rate during the vegetative phase. Leaf number averaged 16.66 and 17.73 per plant at 30 days sampling during summer 1983 and 1984 respectively. While in kharif it was limited to 10.49. With ontogeny to the reproductive phase leaf number further increased from bud stage (22.22, 23.90 and 16.70) to a maximum at flowering (25.45, 24.23 and 20.79). Thenonwards, the number of active leaves declined progressively till maturity (7.09, 10.30 and 10.65).

Planting system had no effect on the number of leaves per plant at any stage in the summer seasons. In kharif, the sole crop registered slightly more number of leaves, than in intercrop system that were significantly different at bud and flowering stages. This effect, however, was mitigated at other phenological stages and the differences were not significant.

A change in the row spacing had no consistent trend and the differences were not significant in any season. Nevertheless, wider rows during summer 1983 exceptionally retained significantly more number of leaves at seed filling (75 days) and maturity (90 days).

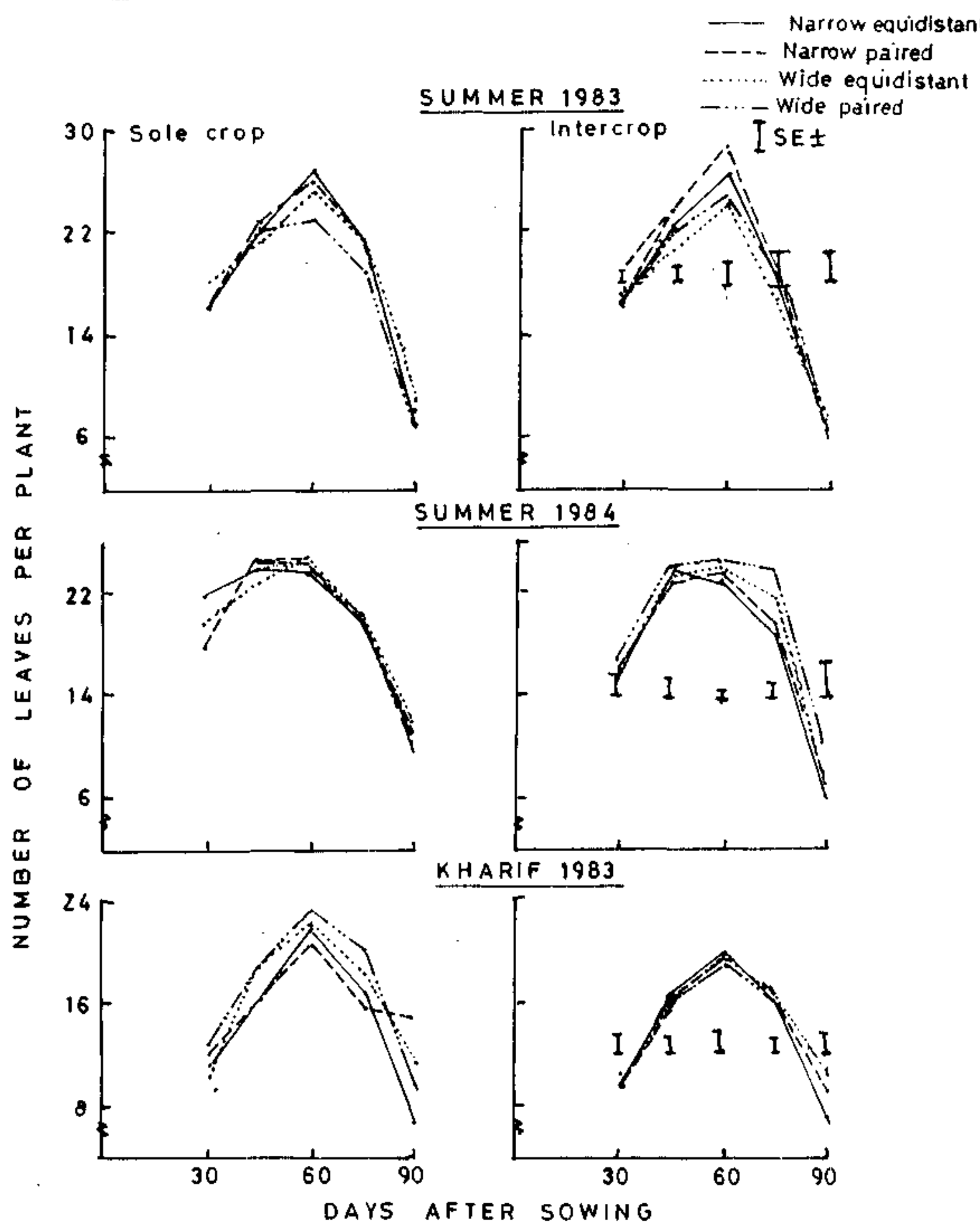


Fig: 5 - NUMBER OF LEAVES PER PLANT OF SUNFLOWER AS INFLUENCED BY PLANTING GEOMETRY IN SOLE AND INTERCROP SYSTEM

The effect of row arrangement in an equidistant or paired pattern was broadly similar with no statistically distinct variation in the number of leaves per plant at any stage.

None of the factors except planting system and method at bud stage and at maturity during summer, 1983 interacted significantly.

4.1.1.3 Leaf area per plant (cm^2)

The mean leaf area per plant increased at a very fast rate during the vegetative phase (Fig.6). By 30 days the attained leaf area was 897.46 and 870.89 cm^2 $plant^{-1}$ in the summer seasons during 1983 and 1984, while in kharif, 1983 it was 304.97 cm^2 $plant^{-1}$. Leaves further expanded during the reproductive phase from bud formation stage (2300.81, 2781.62 and 1165.20 cm^2 $plant^{-1}$) and peaked at flowering (3132.66, 3063.46 and 1236.43 cm^2 $plant^{-1}$). The leaf area retained per plant, then declined towards maturity. At harvest leaf area per plant was limited to 1081.10 and 1459.99 cm^2 during the summer seasons and to 953.39 cm^2 during kharif.

The trend in leaf area development in sole/intercrop system of sunflower with groundnut was not consistent during summer seasons. Whereas, in kharif similar trend was observed except at seed filling when the sole crop of sunflower had significantly larger leaf area than in sunflower intercropped with groundnut.

Method of planting sunflower in rows close together or distant apart was not critical in determining the leaf area.

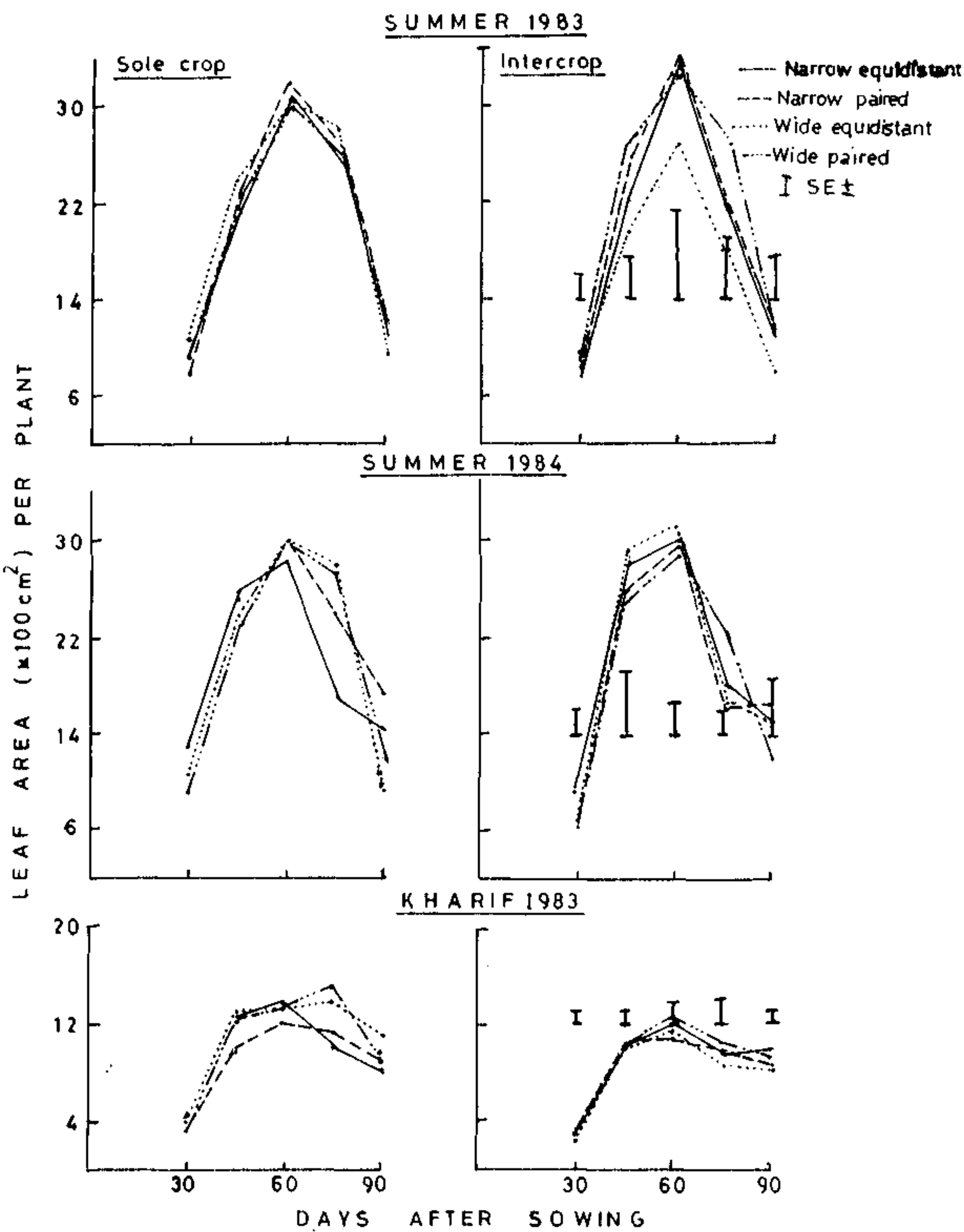


Fig.6 - LEAF AREA PER PLANT OF SUNFLOWER AS INFLUENCED BY PLANTING GEOMETRY IN SOLE AND INTERCROP SYSTEM

Response to row widths in summer seasons was not significantly different. In *kharif*, the leaf area in wider rows exhibited marginal difference.

No definite trend and significant influence on the development of leaf area was found due to equidistant/paired row pattern of planting in the three seasons.

Interactions between any two factors were not effective in altering the leaf area per plant of sunflower significantly in any season. The second order interaction was significant at seed filling stage during summer, 1984.

4.1.1.4 Phytomass accumulation

The shoot phytomass of each plant was partitioned as leaf, stem and capitulum at various phenophases of crop growth to evaluate the effects of different treatments.

4.1.1.4.1 Leaves:

The mean phytomass accumulation in leaves increased from 3.40, 5.15 and 1.29 g $plant^{-1}$ at the vegetative phase during the summer seasons of 1983, 1984 and *kharif* 1983 to a maximum of 23.45, 19.87 and 5.73 g $plant^{-1}$ at flowering during the corresponding seasons (Table 6). Leaves retained on the plant then indicated a progressive fall-off in weight till maturity (9.62, 10.36 and 5.63g $plant^{-1}$). Except at bud stage during the *kharif* season, the leaf phytomass was not influenced significantly by the different treatments at any stage in the three seasons.

Table 6. Phytomass accumulation in leaves of sunflower (g per plant) as influenced by different treatments

Treatment	Days after sowing														
	30		45		60		75		90		30	45	60	75	90
	Summer										Kharif				
	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984	1983				
SNE	4.10	8.02	13.95	16.02	21.90	16.83	20.35	12.04	9.20	9.71	1.31	6.04	6.98	5.05	4.65
SNP	4.02	5.45	13.47	14.48	22.26	20.90	24.77	12.19	12.96	13.78	1.46	4.35	5.54	5.12	5.09
SWE	3.11	5.12	12.90	18.47	24.00	19.88	23.10	12.88	6.48	10.69	1.86	6.96	6.55	7.41	6.97
SWP	3.77	6.05	13.77	23.98	22.82	23.08	24.64	11.61	14.15	7.07	1.70	5.55	6.84	7.38	7.16
INE	3.11	6.59	14.48	16.90	25.16	20.49	16.95	12.58	10.16	9.70	0.94	3.44	5.58	5.79	6.14
INP	2.77	3.34	14.64	18.26	23.92	19.57	16.75	12.10	8.49	12.20	1.20	3.99	4.46	4.93	4.94
IWE	3.28	3.56	13.47	19.66	21.08	20.21	16.06	11.17	5.87	9.83	0.85	3.97	5.08	4.76	4.59
IWP	3.07	3.11	13.51	14.42	26.49	17.97	18.32	16.31	9.63	9.92	1.00	3.64	4.86	5.00	5.57
SE ±	0.94	1.51	2.42	4.21	4.75	2.29	4.42	1.45	5.07	3.97	0.57	0.75	1.69	1.82	1.21
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.61	NS	NS	NS
Mean	3.40	5.15	13.77	17.77	23.45	19.87	20.11	12.61	9.62	10.36	1.29	4.74	5.73	5.68	5.63
S x M															
SN	4.06	6.73	13.71	15.25	22.08	18.87	22.56	12.12	11.08	11.75	1.38	5.20	6.26	5.08	4.87
SW	3.44	5.59	13.33	21.23	23.41	21.48	23.87	12.25	10.31	8.88	1.78	6.27	6.70	7.39	7.06
IN	2.94	4.97	14.56	17.58	24.54	20.03	16.85	12.34	9.32	10.95	1.07	3.71	5.02	4.86	5.54
IW	3.17	3.34	13.49	17.04	23.79	19.09	17.19	13.74	7.75	9.87	0.92	3.81	4.97	4.88	5.08
S x P															
SE	3.60	6.57	13.43	17.24	22.95	18.36*	21.72	12.46	7.84	10.20	1.58	6.51*	6.76	6.23	5.81
SP	3.90	5.75	13.62	19.23	22.54	21.99	24.71	11.90	13.56	10.42	1.58	4.95	6.19	6.25	6.12
IE	3.19	5.08	13.97	18.28	23.13	20.35	16.51	11.87	8.02	9.76	0.89	3.71	5.33	4.77	5.37
IP	2.92	3.23	14.08	16.34	25.21	18.77	17.54	14.21	9.06	11.06	1.10	3.81	4.66	4.97	5.25
M x P															
NE	3.60	7.31	14.22	16.46	23.54	18.66	18.65	12.31	9.68	9.70	1.13	4.74	6.28	4.92	5.39
NP	3.39	4.39	14.06	16.37	23.09	20.23	20.76	12.15	10.72	12.99	1.33	4.17	5.00	5.02	5.01
WE	3.19	4.34	13.18	19.07	22.54	20.05	19.58	12.03	6.18	10.26	1.35	5.48	5.82	6.08	5.78
WP	3.42	4.58	13.64	19.20	24.66	20.53	21.48	13.96	11.89	8.49	1.35	4.59	5.85	6.19	6.36
SE ±	0.66	1.07	1.71	2.98	3.36	1.62	3.12	1.02	3.58	2.81	0.40	0.53	1.19	1.28	0.86
CD 5%	NS	NS	NS	NS	NS	3.47	NS	NS	NS	NS	NS	1.14	NS	NS	NS
System															
S	3.75	6.16*	13.53	18.23	22.75	20.17	23.22	12.18	10.70	10.31	1.58	5.73*	6.48	6.24	5.97
I	3.05	4.15	14.02	17.31	24.17	19.56	17.02	13.04	8.54	10.41	1.00	3.76	5.00	4.87	5.31
Method															
N	3.50	5.85	14.14	16.41	23.31	19.45	19.71	12.23	10.20	11.34	1.23	4.46	5.64	4.97	5.20
W	3.31	4.45	13.41	19.13	23.60	20.29	20.53	13.00	9.04	9.37	1.35	5.04	5.83	6.14	6.07
Pattern															
E	3.40	5.82	13.70	17.76	23.04	19.35	19.11	12.17	7.93	9.98	1.24	5.11	6.05	5.50	5.59
P	3.41	4.49	13.85	17.79	23.87	20.38	21.12	13.05	11.31	10.74	1.34	4.38	5.43	5.60	5.69
SE ±	0.47	0.76	1.71	2.10	2.38	1.15	2.21	0.72	2.53	1.98	0.28	0.37	0.84	0.91	0.61
CD 5%	NS	1.62	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.80	NS	NS	NS

The phytomass accumulation in leaves was not influenced due to sole/inter crop system in the summer seasons except at 30 days during summer 1984. In *kharif*, the sole crop consistently registered a higher dry matter accumulation of leaves than in the intercrop system. However, this effect was not significant except at bud stage.

Response to a change in the row width was not significantly different within each sampling stage. Leaves on plants with wider row spaces marginally outweighed those with narrow row treatment in *kharif*, while, no pertinent trend was observed in the summer seasons.

Leaf phytomass from equidistant/paired row plantings were not statistically dissimilar at any stage during the three seasons.

The first order interactions were not significant at any stage in the three seasons except between the planting system and pattern at bud stage during the *kharif* season. The higher order interactions were significant at seed filling stage during summer, 1984.

4.1.1.4.2 Stem

The mean phytomass apportioned in the stem increased from 1.54 g plant^{-1} during summer, 1983 and 1.44 g plant^{-1} during summer, 1984 at 30 days sampling till the maximum weight of 29.63 and 25.24 g plant^{-1} was recorded at flowering stage (60 days). In *kharif* it increased from 0.46 g plant^{-1} at 30 days to a maximum of 14.43 g plant^{-1} at seed filling stage (75 days). Once the maximum weight was put on, the phytomass accumulation ceased and the weight remained nearly constant with little decline towards maturity. At harvest, dry stem per plant weighed 23.58 and 19.01 g in the summer seasons and 13.59 g in kharif. The treatment effects were significant only at 45 days in the summer season during 1984 (Table 7).

The phytomass accumulation due to the system of planting sunflower in sole/intercrop system with groundnut did not differ significantly in the summer seasons except at 45 days sampling in 1984. Similarly, the monoculture in kharif season significantly outweighed the phytomass of stem in intercrop system only at 30 and 45 days samplings. The modest increase of phytomass in monoculture during the subsequent samplings overshadowed the statistical significance.

The performance of sunflower in response to differential row widths was not consistent and significantly different in the summer seasons. Conversely, wider rows in kharif registered higher amount of phytomass accumulation in the stem, though the differences were significant only at 30 and 75 days.

The relationship of planting pattern in rows spaced at a uniform distance/paired arrangement did not show a significantly differential response to the accumulation of phytomass in the stem at any sampling stage.

Table 7. Phytomass accumulation in stem of sunflower (g per plant) as influenced by different treatments

Treat-ment	Days after sowing														
	30		45		60		75		90		30	45	60	75	90
	Summer										Kharif				
	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984	1983				
SNE	1.78	1.67	9.15	14.05	26.96	22.67	26.65	22.70	25.99	19.53	0.35	2.85	8.80	11.89	11.69
SNP	1.94	1.89	8.37	13.22	32.60	29.19	28.43	24.12	24.63	19.38	0.52	2.23	9.05	12.95	13.93
SWE	1.34	1.42	7.83	10.00	31.10	22.90	26.33	21.63	21.92	19.01	0.54	3.08	9.11	18.62	16.75
SWP	1.44	1.89	8.57	12.71	29.00	27.43	29.57	25.25	25.36	17.28	0.75	3.09	9.62	19.43	13.65
INE	1.61	1.96	10.35	13.14	28.77	27.32	20.94	21.69	20.91	18.67	0.34	2.12	10.06	12.95	13.59
INP	0.99	0.90	8.85	7.43	28.80	24.63	22.45	26.16	20.54	19.27	0.35	1.80	8.05	11.79	13.41
IWE	1.77	0.95	8.60	8.26	26.43	25.61	24.06	23.59	22.82	19.93	0.42	2.12	10.25	12.70	12.80
IWP	1.50	0.84	8.54	9.40	33.45	22.19	27.36	25.77	26.28	19.07	0.41	1.85	7.09	15.13	12.95
SE ±	0.58	0.61	1.82	2.17	6.52	2.74	5.48	2.59	5.82	3.11	0.12	0.48	2.62	3.13	2.22
CD 5%	NS	NS	NS	4.66	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
GM	1.54	1.44	8.78	11.02	29.63	25.24	25.72	23.86	23.58	19.01	0.46	2.39	9.00	14.43	13.59
S x M															
SN	1.86	1.78	8.76	13.68	29.78	25.93	27.54	23.41	25.41	19.45	0.44	2.54	8.92	12.42	12.81
SW	1.39	1.65	8.20	11.36	30.05	25.16	27.95	23.44	23.64	18.15	0.64	3.08	9.36	19.03	15.20
IN	1.30	1.43	9.60	10.28	28.78	25.98	21.69	23.93	20.72	18.97	0.35	1.96	9.05	12.37	13.50
IW	1.64	0.90	8.57	8.83	29.94	23.90	25.68	24.66	24.55	19.50	0.41	1.98	8.67	13.92	12.87
S x P															
SE	1.56	1.54	8.49	12.03	29.03	22.78*	26.49	22.17	23.95	19.27	0.45	2.97	8.95	15.26	14.22
SP	1.69	1.89	8.47	13.00	30.80	28.31	29.00	24.68	25.10	18.33	0.63	2.66	9.33	16.19	13.79
IE	1.69	1.45	9.48	10.70	27.60	26.47	22.47	22.64	23.41	19.30	0.38	2.12	10.15	12.82	13.19
IP	1.25	0.87	8.69	8.41	31.12	23.41	24.91	25.95	21.86	19.17	0.38	1.82	7.57	13.46	13.18
M x P															
NE	1.69	1.81	9.75	13.59*	27.87	24.99	23.80	22.19	23.45	19.10	0.35	2.49	9.43	12.42	12.64
NP	1.47	1.40	8.61	10.37	30.70	26.91	25.44	24.14	22.69	19.32	0.44	2.01	8.55	12.37	13.67
WE	1.56	1.18	8.22	9.13	28.77	24.25	25.17	22.61	22.37	19.47	0.48	2.60	9.68	15.66	14.77
WP	1.47	1.37	8.56	11.05	31.23	24.81	28.47	25.49	21.86	18.17	0.58	2.47	8.35	17.28	13.30
SE ±	0.41	0.43	1.34	1.53	4.61	1.93	3.87	1.83	4.12	2.02	0.09	0.34	1.88	2.23	1.57
CD 5%	NS	NS	NS	3.27	NS	4.16	NS	NS	NS	NS	NS	NS	NS	NS	NS
System															
S	1.63	1.72	8.48	12.52*	29.92	25.55	27.75	23.42	27.75	18.80	0.54*	2.81*	9.14	15.72	14.00
I	1.47	1.16	9.08	9.56	29.36	24.94	29.36	24.30	29.36	19.23	0.38	1.97	8.86	13.14	13.19
Method															
N	1.58	1.60	9.18	11.98	29.28	25.95	24.62	23.67	23.06	19.21	0.39*	2.25	8.99	12.40*	13.16
W	1.52	1.27	8.39	10.09	29.99	24.53	26.82	24.05	24.09	18.82	0.53	2.53	9.02	16.47	14.04
Pattern															
E	1.63	1.50	8.99	11.36	28.32	24.62	24.48	22.60	22.91	19.28	0.41	2.54	9.55	14.04	13.71
P	1.47	1.38	8.58	10.71	30.96	25.86	26.95	25.30	24.25	18.75	0.51	2.24	8.45	14.83	13.48
SE ±	0.29	0.31	0.95	1.08	3.26	1.37	2.74	1.29	2.91	1.56	0.06	0.24	1.31	1.57	1.11
CD 5%	NS	NS	NS	2.33	NS	NS	NS	NS	NS	NS	0.13	0.51	NS	3.38	NS

None of the interactions except planting system and pattern at 60 days, while planting method and pattern at 45 days during summer, 1984 were found significant. The second order interactions were not significant at any stage.

4.1.1.4.3 Capitulum

The mean phytomass of the reproductive material increased from 0.92 and 2.85 g $plant^{-1}$ at bud formation to 19.85 and 21.72 g $plant^{-1}$ at flowering stage in the summer seasons. Gain in mass further continued with crop age registering a dry weight of 25.39 and 32.38 g $plant^{-1}$ at seed filling (75 days) while the final weight at maturity was 33.01 and 39.25 g $plant^{-1}$ during summer, 1983 and 1984 respectively. In kharif, buds developed less rapidly registering a mean phytomass of only 0.87 g $plant^{-1}$ at 45 days which rose to 3.08 g $plant^{-1}$ in the capitulum at flowering (60 days) and 12.60 g $plant^{-1}$ at seed filling (75 days). At harvest the capitulum on an average weighed 19.45 g $plant^{-1}$ (Table 8).

The associated growth of sunflower with groundnut did not show a considerable contrast with the phytomass of capitulum in monoculture. The only significant reductions in the phytomass of reproductive structures in the intercrop system were recorded at bud stage during summer, 1984 and at seed filling stage during kharif, 1983.

Analysis of variance showed that the planting method had no significant effect on the phytomass accumulation of capitulum irrespective of the crop sown in narrow or wide rows.

Table 6. Phytomass accumulation in capitulum of sunflower (g per plant) as influenced by different treatments

Treatment	Summer 45 DAS 1983	Summer 45 DAS 1984	Summer 60 DAS 1983	Summer 60 DAS 1984	Summer 75 DAS 1983	Summer 75 DAS 1984	Summer 90 DAS 1983	Summer 90 DAS 1984	Kharif 1983 45 DAS	Kharif 1983 60 DAS	Kharif 1983 75 DAS	Kharif 1983 90 DAS
SNE	0.52	3.45	17.07	22.26	24.30	36.18	28.37	43.18	0.9[illegible]	2.68	12.18	18.70
SNP	0.85	3.73	18.70	23.80	28.70	37.00	34.82	38.71	0.80	2.90	12.45	19.46
SWE	1.17	2.93	20.86	21.10	25.20	29.90	31.49	34.52	0.75	2.69	16.39	22.13
SWP	1.37	3.77	20.51	19.80	23.80	30.00	39.05	40.42	0.86	4.08	18.17	22.83
INE	0.93	4.30	18.73	23.90	26.90	28.00	36.30	34.93	1.08	2.75	11.63	17.99
INP	0.83	1.59	20.86	21.10	24.10	31.00	29.48	38.64	0.75	3.31	9.26	20.10
IWE	0.93	1.62	21.34	19.85	24.15	33.00	29.88	41.99	0.60	2.73	10.23	16.05
IWP	0.86	1.41	20.77	22.00	26.00	34.00	34.71	41.62	1.23	3.53	10.53	18.40
SE ±	0.35	0.72	3.49	2.42	3.90	5.70	4.12	4.88	0.38	1.19	3.38	3.62
CD 5%	NS	1.55	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean	0.92	2.85	19.85	21.72	25.39	32.38	33.01	39.25	0.87	3.08	12.60	19.45
S x M												
SN	0.69	3.59	17.89	23.03	26.50	36.59	31.59	40.94	0.85	2.79	11.81	19.08
SW	1.27	3.35	20.68	20.45	24.50	29.95	35.27	37.47	0.80	3.39	17.28	22.48
IN	0.88	2.94	19.80	22.50	22.50	29.50	32.89	36.78	0.91	3.03	10.45	19.04
IW	0.90	1.52	21.21	20.92	25.07	33.50	32.29	41.80	0.91	3.13	10.38	17.22
S x P												
SE	0.85	3.19	18.96	21.68	24.75	33.04	29.93	38.85	0.82	2.68	13.78	20.41
SP	1.11	3.75	19.61	21.80	26.25	33.50	36.93	41.80	0.83	3.49	15.31	21.14
IE	0.93	2.96	20.28	21.87	25.52	30.50	33.09	38.46	0.91	2.74	10.93	17.02
IP	0.85	1.50	20.72	21.55	25.05	32.50	32.09	40.13	0.99	3.42	9.89	19.25
M X P												
NE	0.98	3.87	17.90	23.08	25.60	32.09	33.71	39.05	0.99	2.71	11.40	18.34
NP	0.54	2.66	19.78	22.45	26.60	34.00	32.15	38.67	0.77	3.10	10.85	19.78
WE	1.05	2.28	21.34	20.47	24.67	31.45	30.68	38.25	0.91	2.71	13.31	19.09
WP	1.11	2.59	20.55	20.90	24.90	32.00	36.88	41.02	0.99	3.81	14.35	20.61
SE ±	0.25	0.51	2.47	1.64	3.15	4.03	3.37	3.77	0.27	0.84	2.39	2.54
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
System												
S	0.98	3.47*	19.29	21.74	25.50	33.27	33.43	39.20	0.83	3.09	14.55*	20.78
I	0.87	2.23	20.50	21.71	25.29	31.50	32.59	39.29	0.91	3.08	10.41	18.13
Method												
N	0.76	3.27	18.84	22.76	26.00	33.04	32.24	38.86	0.88	2.91	11.13	19.06
W	1.08	2.43	20.95	20.69	24.79	31.72	33.78	39.64	0.86	3.26	13.83	20.28
Pattern												
E	1.01	3.08	19.62	21.78	25.14	31.77	31.51	38.65	0.83	2.71	12.36	18.72
P	0.83	2.62	20.16	21.67	25.65	33.00	34.51	39.85	0.91	3.46	12.60	20.20
SE ±	0.17	0.36	1.75	1.05	2.40	3.64	2.56	3.06	0.17	0.59	1.69	1.81
CD 5%	NS	0.78	NS	NS	NS	NS	NS	NS	NS	NS	3.63	NS

The paired row pattern in general tended to accumulate marginally greater amount of phytomass than in the uniform row spacings, but, the differences were not significant at any stage in the three seasons.

The first order as well as the second order interactions were not significant.

4.1.1.5 Capitulum diameter (cm), number of seeds per capitulum and thousand seed weight (g)

The mean capitulum diameter across treatments was 14.09 and 15.80 cm in the summer seasons while 10.90 cm in *kharif* (Table 9). Seeds per capitulum were 346.51 and 333.97 in the summer seasons during 1983 and 1984. While during *kharif*, 1983 the seed number per capitulum was 307.68. The thousand seed weight was 52.78, 54.0 and 41.29 g during the corresponding season.

Performance of sunflower in intercrop system was as good as in sole crop with a marginal reduction in capitulum diameter, number of seeds per capitulum and the test weight. Planting systems had no significant influence on any of these parameters.

Planting method indicated that the narrow rows had a slight edge over the wider row spacings in the summer seasons, while, the reverse was true in *kharif*. However, the differences were not significant in any season.

Table 9 : Capitulum diameter (cm), number of seeds per capitulum and thousand seed weight (g) of sunflower as influenced by different trealtments

Treat-ment	Capitulum diameter (cm)			Number of seeds per Capitulum			Thousand-seed weight (g)		
	Summer		Kharif	Summer		Kharif	Summer		Kharif
	1983	1984	1983	1983	1984	1983	1983	1984	1983
SNE	14.47	14.07	10.40	389.31	404.62	317.03	54.60	54.67	41.60
SNP	14.67	15.87	10.73	346.70	351.25	330.03	55.28	55.32	40.12
SWE	13.97	14.93	11.53	386.11	327.67	326.93	53.21	52.64	43.65
SWP	14.43	14.00	11.53	331.59	310.56	331.28	50.72	54.00	44.95
INE	15.33	15.40	10.47	352.61	315.63	284.94	52.09	53.21	39.62
INP	13.53	13.87	10.87	321.78	335.53	319.88	52.20	54.60	40.95
IWE	13.47	14.13	10.53	318.23	307.65	269.77	51.12	52.80	38.87
IWP	12.86	14.20	11.20	325.77	318.89	281.61	53.06	54.90	40.58
SE ±	1.32	1.18	1.10	68.07	50.42	80.19	5.10	4.80	3.42
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean	14.09	15.80	10.90	346.51	333.97	307.68	52.78	54.00	41.29
S x M									
SN	14.57	14.97	10.57	389.31	377.93	323.53	54.94	54.99	40.86
SW	14.20	14.46	11.53	358.85	319.11	329.10	51.96	53.32	44.30
IN	14.43	14.63	10.67	337.19	325.58	302.41	52.14	53.90	40.28
IW	13.16	14.16	10.87	322.00	313.27	275.69	52.09	53.85	39.72
S x P									
SE	14.22	14.50	10.97	387.71	366.14	321.98	53.90	53.65	42.62
SP	14.55	14.93	11.13	339.14	330.90	330.65	53.00	54.66	42.54
IE	14.40	14.76	10.50	335.42	311.64	277.35	51.60	53.00	39.24
IP	13.19	14.09	11.03	323.77	327.21	300.75	52.63	54.75	40.76
M x P									
NE	14.90	14.73	10.43	370.96	360.12	300.98	53.34	53.94	40.61
NP	14.10	14.87	10.80	334.24	343.39	324.96	53.74	54.96	40.53
WE	13.72	14.53	11.03	352.17	317.66	298.35	52.16	52.72	41.26
WP	13.64	14.10	11.37	328.68	314.72	306.44	51.89	54.45	42.76
SE ±	0.93	0.83	0.77	42.88	35.78	56.70	3.47	3.39	2.43
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
System									
S	14.38	14.71	11.05	363.43	348.52	326.32	53.45	54.16	42.58
I	13.80	14.40	10.77	329.60	319.42	289.05	52.12	53.88	40.00
Method									
N	14.50	14.83	10.62	352.60	351.75	312.97	53.54	54.45	40.57
W	13.68	14.31	11.20	340.42	316.19	302.40	52.02	53.58	42.01
Pattern									
E	14.31	14.63	10.73	361.56	338.39	299.67	52.75	53.33	40.93
P	13.87	14.48	11.08	331.46	329.06	315.70	52.81	54.70	41.65
SE ±	0.66	0.58	0.77	30.69	25.30	40.10	2.85	2.40	1.73
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

Similarly, the changed row pattern of either equidistant or paired row arrangement did not influence any of these parameters significantly.

The treatment effects were all independent and did not interact at the lower or higher order.

4.1.1.6 Oil per cent, seed and oil yield per plant (g)

Oil percentage of sunflower was independent of the treatment effects and did not differ significantly. Sunflower achenes on an average contained 37.4% oil during summer seasons and 38.4% in kharif. The mean seed yield per plant was 18.75 g during summer 1983, 18.54 g during summer 1984 and 12.26 g during kharif, 1983. The oil content averaged 7.05, 6.94 and 4.73 g plant^{-1} in the respective seasons (Table 10).

Seed and oil yield per plant were little affected in the intercrop system. But, the marginal differences between sole and intercrop system were not amplified significantly. Similarly, the method of planting in changed row spaces or the pattern of planting in equidistant or paired rows were not critical to influence the seed or oil yield per plant.

Significant response to the interaction of factors both at the lower and higher order were not manifested.

4.1.1.7 Seed yield (kg ha^{-1})

Sunflower performed better in the summer seasons with a mean yield of 1347.96 and 1371.04 kg ha^{-1} during 1983

Table 10. Oil per cent, seed yield (g per plant) and oil yield (g per plant) of sunflower as influenced by different treatments

Treatment	Oil per cent			Seed yield pl^{-1} (g)			Oil yield pl^{-1} (g)		
	Summer		Kharif	Summer		Kharif	Summer		Kharif
	1983	1984	1983	1983	1984	1983	1983	1984	1983
SNE	37.3	36.9	38.7	20.50	21.23	12.58	7.72	7.84	4.93
SNP	38.1	38.1	38.8	18.83	19.67	13.02	7.27	7.51	5.19
SWE	38.3	39.0	39.0	20.85	18.35	14.10	8.03	7.21	5.51
SWP	35.1	36.0	38.0	17.96	18.51	14.89	6.32	6.66	5.69
INE	38.1	37.2	36.8	18.63	17.67	10.72	7.10	6.59	3.98
INP	37.2	36.9	38.4	18.02	18.23	12.78	6.73	6.74	4.93
IWE	38.2	37.8	38.1	17.75	17.22	8.88	6.80	6.51	3.37
IWP	37.2	37.1	38.9	17.49	17.41	11.14	6.48	6.46	4.27
SE ±	2.0	0.9	1.8	5.99	2.67	3.57	1.28	1.11	1.41
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean	37.4	37.4	38.4	18.75	18.54	12.26	7.05	6.94	4.73
S x M									
SN	37.8	37.5	38.8	19.66	20.45	12.80	7.49	7.67	5.06
SW	36.7	37.5	38.6	19.40	18.43	14.49	7.17	6.94	5.60
IN	37.7	37.0	37.6	18.32	17.95	11.75	6.91	6.66	4.46
IW	37.6	37.4	38.5	17.62	17.31	10.01	6.64	6.48	3.82
S x P									
SE	37.8	37.9	38.9	20.67	17.79	13.34	7.87	7.53	5.22
SP	36.7	37.0	38.5	18.39	19.09	13.96	6.79	7.08	5.44
IE	38.2	37.5	37.5	18.19	17.44	9.80	6.95	6.55	3.68
IP	37.1	37.0	38.7	17.75	17.82	11.96	6.40	6.60	4.60
M x P									
NE	37.7	37.0	37.7	19.56	19.45	11.65	7.41	7.21	4.46
NP	37.8	37.5	38.7	18.42	18.95	12.90	7.00	7.12	5.06
WE	38.3	38.4	38.6	19.30	17.78	11.49	7.41	6.86	4.44
WP	36.1	36.5	38.5	17.72	17.96	13.01	6.40	6.56	4.98
SE ±	1.4	0.7	1.3	4.23	1.88	2.52	0.92	0.79	1.00
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
System									
S	37.3	37.5	38.7	19.53	19.44	13.65	7.33	7.31	5.33
I	37.6	37.2	38.1	17.97	17.63	10.88	6.78	6.57	4.14
Method									
N	37.7	37.3	38.2	19.66	19.20	12.28	7.20	7.17	4.76
W	37.2	37.5	38.6	19.40	17.87	12.25	6.91	6.71	4.71
Pattern									
E	38.0	37.7	38.2	19.43	18.62	11.57	7.41	7.04	4.45
P	37.0	37.0	38.6	18.07	18.45	12.96	6.70	6.84	5.02
SE ±	1.0	0.5	0.9	2.99	1.33	1.79	0.64	0.55	0.71
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

and 1984 respectively. The mean yield in *kharif* was limited to 816.16 kg ha^{-1}. The treatment effects were significant in the *kharif* season while the differences in yield were not significant in either of the summer seasons (Table 11).

Sunflower intercropped with groundnut yielded slightly less (1306.14 and 1277.04 ha^{-1}) than the sole crop (1389.79 and 1465.89 kg ha^{-1}) in the summer seasons. The absolutely narrow differences in yield, however, overshadowed the F-test to reach the level of statistical significance. In *kharif*, sole crop of sunflower yielded (940.55 kg ha^{-1}) significantly more than that intercropped (663.64 kg ha^{-1}) with groundnut.

Planting method indicated that the seed yield in narrow row treatments (1387.97, 1452.63 and 828.50 kg ha^{-1}) had an edge over the wider row treatments (1307.95, 1290.31 and 775.68 kg ha^{-1}) in the summer seasons during 1983, 1984 and *kharif*, 1983. But the differences were not significant.

Seed yield with equidistant row arrangement in the summer seasons during 1983 (1426.62 kg ha^{-1}) and 1984 (1388.90 kg ha^{-1}) yielded more than the paired row pattern (1296.30 and 1354.03 kg ha^{-1}). But, in the *kharif* season, paired row pattern registered marginally higher yield (809.45 kg ha^{-1}) than in the equidistant row arrangement (794.74 kg ha^{-1}). However, these marginal differences in yield were not significant in any season.

The first order as well as the second order interactions were not significant in any season.

The mean performance of sunflower over the summer seasons assessed by the pooled analysis of variance showed that the seed yield per hectare was not significantly influenced by the different treatments. The sole crop yielded 1427.84 kg ha^{-1} while in intercrop system the mean production was 1291.59 kg ha^{-1}. Sunflower in the narrow row treatments similarly yielded more (1420.30 kg ha^{-1}) than in wider rows (1299.13 kg ha^{-1}) while in the paired row pattern the yield was less (1311.67 kg ha^{-1}) than in the equidistant row pattern (1407.76 kg ha^{-1}). However, neither the interactions nor the treatment effects were significant.

4.1.1.8 Oil yield (kg ha^{-1})

The mean oil yield of sunflower achenes was 502.20 and 515.91 kg ha^{-1} during summer 1983 and 1984 respectively. In *kharif* it was 308.10 kg ha^{-1}. The effect of different treatments on oil yield was significant in the *kharif* season (Table 11). Planting system indicated that though the out-turn of oil per hectare was more from sole crop of sunflower (514.44 and 550.74 kg ha^{-1}) than that intercropped with groundnut (489.97 and 475.18 kg ha^{-1}) during summer 1983 and 1984 the differences were not significant. In *kharif*, oil yield of 363.88 kg ha^{-1} was obtained from the sole crop which was significantly superior to that of 252.33 kg ha^{-1} from the crop grown in intercrop system.

Plants in narrow rows produced 517.04, 541.32 and 317.42 kg ha^{-1} oil during summer 1983, 1984 and *kharif* 1983 respectively. While, the corresponding oil yield in the wider

Table 11. Seed and oil yield (kg ha^{-1}) of sunflower as influenced by different treatments

Treat-ment	Seed yield kg ha^{-1}				Oil yield kg ha^{-1}			
	Summer		Pooled	Kharif	Summer		Pooled	Kharif
	1983	1984		1983	1983	1984		1983
SNE	1504.72	1682.13	1593.42	919.08	561.09	620.80	590.94	354.46
SNP	1303.81	1523.96	1413.88	930.83	483.72	580.47	532.09	363.06
SWE	1503.75	1327.07	1415.41	971.17	576.40	508.07	542.23	379.38
SWP	1246.86	1330.40	1288.63	941.10	436.54	517.23	476.88	358.60
INE	1444.88	1299.53	1372.20	828.56	548.05	483.53	515.79	263.59
INP	1298.47	1304.87	1301.67	748.08	475.31	480.47	477.89	288.57
IWE	1253.13	1246.86	1249.99	572.67	481.13	469.89	475.51	216.48
IWP	1228.07	1256.89	1242.48	617.79	455.38	466.82	461.10	240.67
SE ±	184.78	188.46	228.58	95.70	60.79	68.82	21.25	37.03
CD 5%	NS	NS	NS	205.28	NS	NS	NS	79.44
Mean	1347.96	1371.04	1359.71	816.16	502.20	515.91	509.05	308.10
S x M								
SN	1404.27	1603.05	1503.65	924.95	544.41	600.63	561.52	358.76
SW	1375.31	1328.73	1352.02	956.14	506.47	500.84	509.56	368.99
IN	1371.67	1302.21	1336.94	732.05	511.68	482.00	496.84	276.08
IW	1240.60	1251.88	1246.24	595.23	468.26	468.35	468.30	228.57
S x P								
SE	1504.24	1504.60	1504.42	945.12	568.75	569.01	566.59	366.92
SP	1275.34	1427.18	1351.26	935.97	460.13	532.46	504.49	360.83
IE	1349.00	1273.20	1311.10	644.35	514.59	476.71	495.65	240.03
IP	1263.26	1280.88	1272.08	682.94	465.35	473.64	469.49	264.62
M x P								
NE	1474.80	1490.83	1482.82	817.55	554.57	552.16	553.37	309.02
NP	1301.14	1414.42	1357.78	839.46	479.51	530.47	504.99	325.82
WE	1378.44	1286.96	1332.70	771.93	528.77	493.56	508.87	297.93
WP	1237.47	1293.64	1265.55	779.44	445.96	475.64	468.99	299.63
SE ±	130.66	133.27	161.33	67.67	42.98	48.67	15.02	26.19
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS
System								
S	1389.79	1465.89	1427.84	940.55*	514.44	550.74	535.54**	363.88*
I	1306.14	1277.04	1291.59	663.64	489.97	475.18	482.57	252.33
Method								
N	1387.97	1452.63	1420.30	828.50	517.04	541.32	529.18**	317.42
W	1307.95	1290.31	1299.13	775.68	487.37	484.60	488.93	298.78
Pattern								
E	1426.62	1388.90	1407.76	794.74	541.67	522.86	531.12**	303.48
P	1269.30	1354.03	1311.67	809.45	462.74	503.05	486.99	312.73
SE ±	92.40	94.23	114.29	47.85	30.39	34.41	10.62	18.51
CD 5%	NS	NS	NS	102.64	NS	NS	21.76	39.72

rows was reduced to 487.37, 484.60 and 298.78 kg ha^{-1} and yet the differences were not significant.

Planting pattern had no significant influence on the oil yield in any of the three seasons and so also the interactions.

The pooled analysis as a mean of summer seasons indicated that the sole crop produced significantly higher quantity of oil (535.54 kg ha^{-1}) compared to the oil yield of sunflower (482.57 kg ha^{-1}) intercropped with groundnut. Likewise, the narrow rows faired exceedingly better (529.18 kg ha^{-1}) than the wider rows (488.93 kg ha^{-1}). The equidistant planting pattern registered significantly higher oil out-turn of 531.12 kg ha^{-1} than the oil yield of 486.99 kg ha^{-1} in the paired row pattern. However, the interactions were not significant.

4.1.2 Neutro-periodism

Results are presented on the per cent elemental concentration of the major nutrients and their uptake as influenced by different treatments at various stages of crop growth.

4.1.2.1 Per cent nutrient composition

The elemental composition for nitrogen, phosphorus and potassium of above ground plant parts as influenced by different treatments are presented separately.

4.1.2.1.1 Nitrogen per cent

Leaf nitrogen declined in mean concentration from 4.84, 3.65 and 2.99% at the vegetative phase (30 days) in the

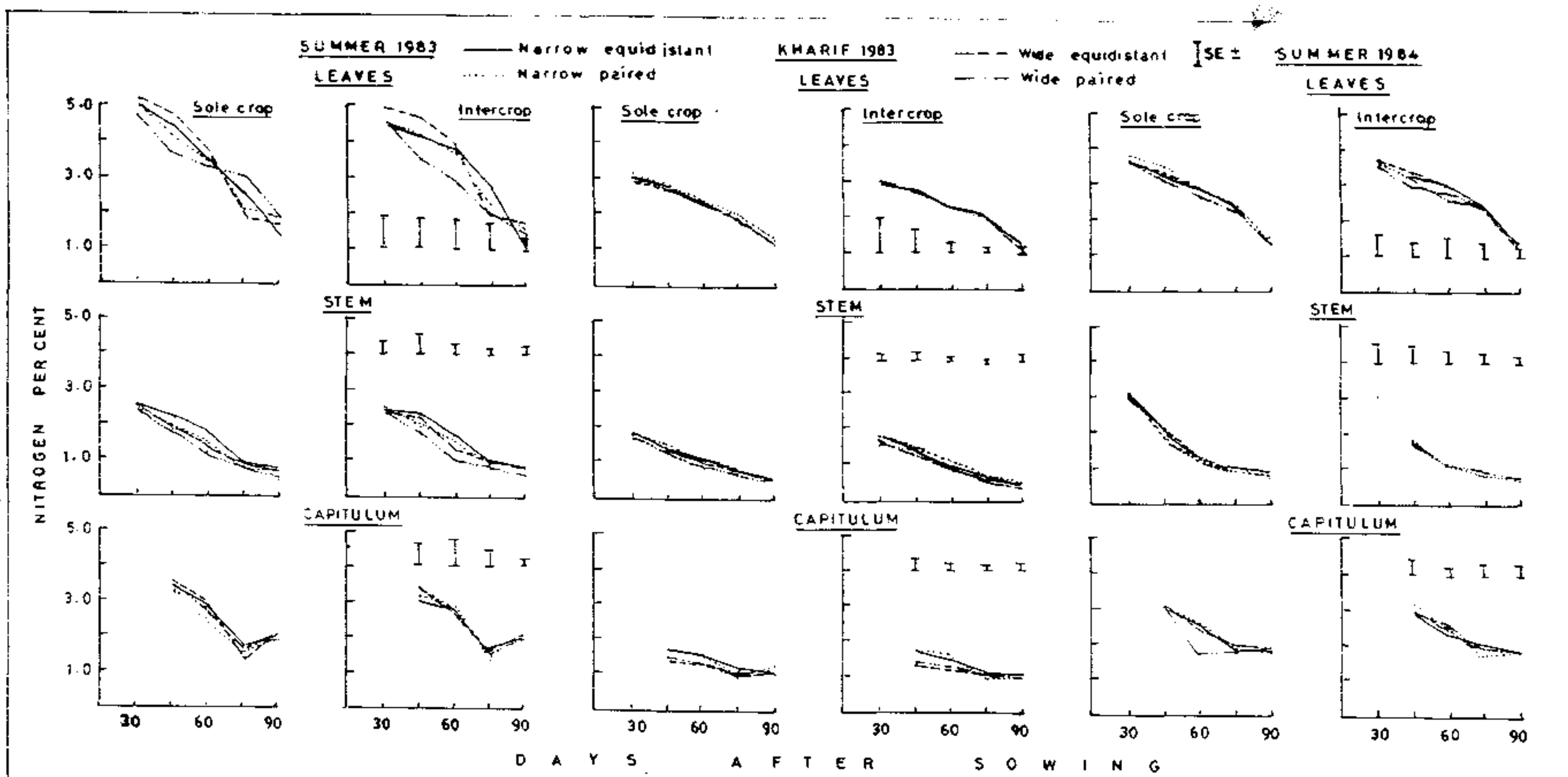


Fig:7- NITROGEN PERCENT IN PLANT PARTS OF SUNFLOWER AS INFLUENCED BY PLANTING GEOMETRY IN SOLE AND INTERCROP SYSTEM respective crop growth seasons of summer 1983, 1984 and <u>kharif</u>, 1983 with crop age till maturity to a minimum of 1.49, 1.36 and 1.22%. Nitrogen in the stem followed a similar trend. It declined steadily from a mean concentration of 2.45, 3.06 and 1.74% at the vegetative phase to 0.76, 0.70 and 0.47% at maturity in the respective seasons. Nitrogen in the reproductive structures declined from 3.33, 3.05 and 1.57% in the flower buds to 2.06, 1.81 and 1.08% in the capitulum at maturity. The capitulum at harvest had 0.93, 1.20 and 0.63% nitrogen in the disc while 3.19, 2.43 and 1.53% in the seed (Fig.7).

There were little differences in the concentration of nitrogen element in the leaves, stem, capitulum or the disc and seed between any pair of comparable treatments and their interaction both at the lower and higher level. This indicated a lack of significant response to the varying spatial configuration of sunflower sown sole/intercropped with groundnut. This trend persisted throughout the growth stages in three seasons.

4.1.2.1.2 Phosphorus per cent

Phosphorus in the leaves increased gradually from a mean concentration of 0.27, 0.15 and 0.29% at the vegetative phase (30 days) in summer seasons of 1983, 1984 and <u>kharif</u> 1983, peaked (0.34, 0.26 and 0.45%) at seed filling (75 days) and then declined abruptly to a respective minimum of 0.14, 0.09 and 0.15% at maturity. The concentration in stem followed a similar increasing-decreasing trend with the difference that the peak was shifted earlier to the flowering phase. Phosphorus

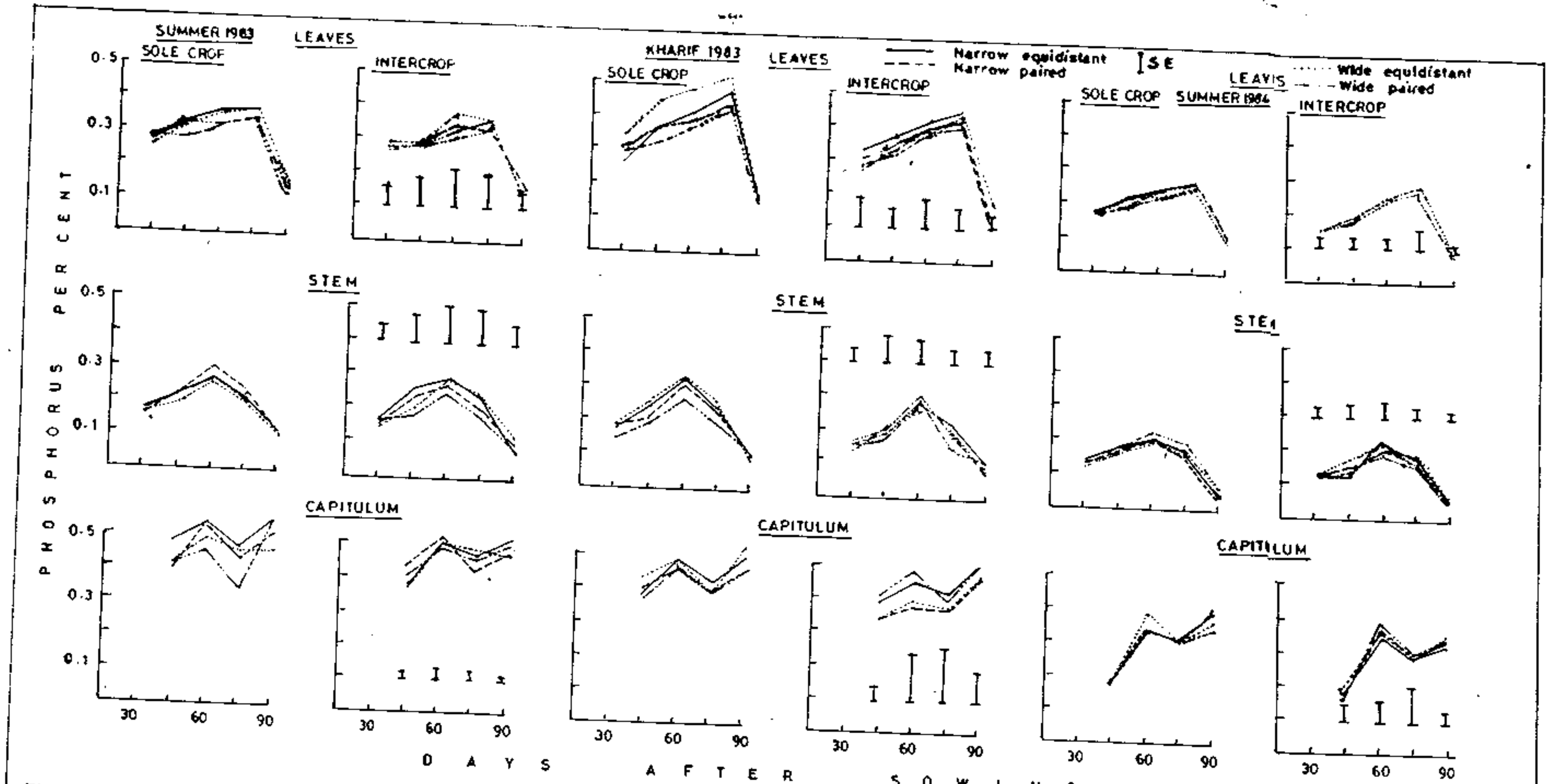


Fig: 8- PHOSPHORUS PERCENT IN PLANT PARTS OF SUNFLOWER AS INFLUENCED BY PLANTING GEOMETRY IN SOLE AND INTERCROP SYSTEM

increased from a concentration of 0.16, 0.13 and 0.15% at the vegetative phase to a maximum of 0.27, 0.21 and 0.29% at flowering and then declined rapidly to 0.10, 0.05 and 0.09% at harvest. Capitulum in general had greater concentrations of phosphorus than the leaves. Phosphorus increased from 0.41, 0.17 and 0.37% in the flowerbuds to 0.51, 0.36 and 0.45% in the capitulum at flowering. The concentration then remained almost constant at maturity (0.50, 0.36 and 0.49%) with a little dip at seed filling (0.44, 0.29 and 0.39%) in each season. Discs of the capitulum at harvest had a considerably lower concentration (0.15, 0.13 and 0.13%) than the seed (0.96, 0.59 and 0.85%) in the three seasons (Fig.8).

The treatment effects were not significant in changing the phosphorus content of leaves, stem or capitulum in any season. Changes in the row width or pattern of row arrangement in a sole/intercrop system revealed that the phosphorus content was influenced neither by the simple effects of treatments nor by their interactions.

4.1.2.1.3 <u>Potassium per cent</u>

The concentration of potassium demonstrated a variable pattern quite distinctly different from the nitrogen and phosphorus percentage (Fig. 9).

The mean concentration in leaves declined from 2.25, 1.58 and 2.12% at the vegetative phase (30 days) in the summer seasons during 1983, 1984 and in <u>kharif</u> season during 1983 to 1.56, 1.12 and 1.51% with ontogeny to the reproductive phase at bud formation stage (45 days). Then it increased rapidly, attained the peak at seed filling (3.73, 2.69 and 3.32%) and remained in consonance till maturity in the summer seasons (3.68 and 2.72%) but declined sharply in kharif (2.47%).

Potassium in the stem similarly declined from 2.05, 2.45 and 2.36% at the vegetative phase to 1.17, 1.05 and 1.38% at bud formation, but, again increased to a maximum of 3.52, 3.29 and 3.35% at seed filling stage in the three seasons. But later, the mean concentration declined sharply at maturity (3.24, 3.13 and 2.97%). The reproductive structures demonstrated a progressive increase in potassium concentration from bud formation (1.21, 1.06 and 1.35%) till seed filling (3.26, 2.53 and 2.54%) and then declined at maturity (2.46, 2.07 and 1.70%). Unlike nitrogen and phosphorus, the capitulum at harvest had greater concentrations of potassium (4.23, 3.49 and 2.82%) in the disc while too little persisted in the seed (0.69, 0.65 and 0.59%).

No remarkable variation in the potassium concentration of leaves, stem, capitulum and disc or seed was apparent due to different treatment at any stage of crop growth. Analysis of variance of the component factors revealed that the comparisons within and between the planting systems, planting methods and the pattern of row arrangement were all statistically similar in their effects.

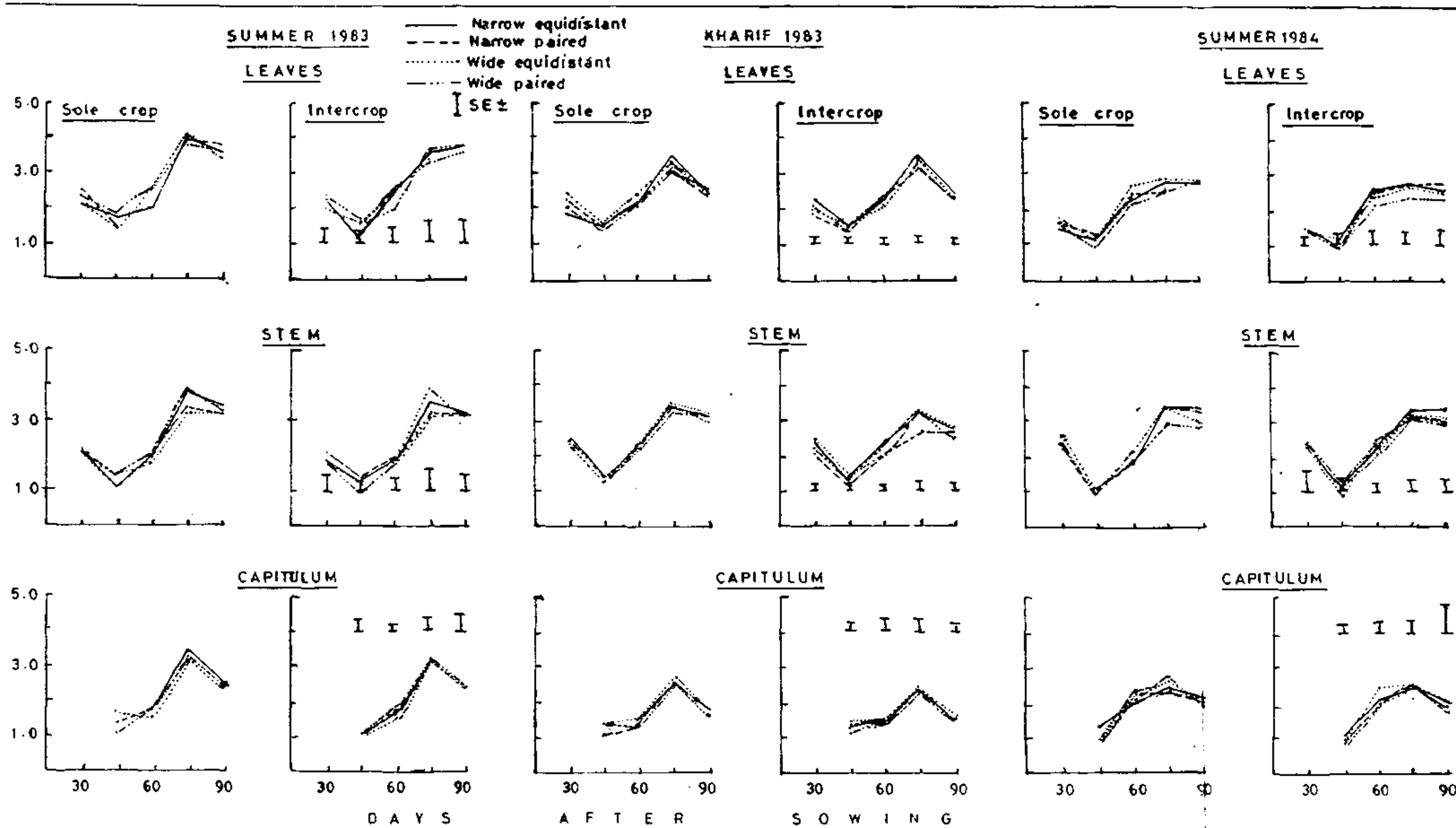


Fig: 9 - POTASSIUM PER CENT IN PLANT PARTS OF SUNFLOWER AS INFLUENCED BY PLANTING GEOMETRY IN SOLE AND INTERCROP SYSTEM

4.1.2.2 Nutrient uptake

The quantum of nutrients absorbed and accumulated in different plant parts as influenced by the crop geometry of sunflower intercropped or not with groundnut are presented separately for each element assayed in the study.

4.1.2.2.1 Nitrogen

a. **Leaves:** Nitrogen accumulation in the leaves increased with crop age till the flowering stage, but declined subsequently in the later stages (Table 12). Leaves in the vegetative phase removed 165.4, 188.6 and 38.7 mg N plant^{-1} during summer 1983, 1984 and *kharif* 1983 respectively. The uptake further enhanced with the highest removal coinciding with flowering stage in summer and *kharif* seasons (825.09 and 132.4 mg N) during 1983, while the peak was attained at bud stage (573.00 mg N plant^{-1}) during summer, `1984. The mean uptake then narrowed down till harvest (144.9, 141.7 and 69.2 mg N plant^{-1}). The treatment effects were significant at bud and flowering stages in the *kharif* season.

The quantity of nitrogen removed by the leaves did not show a perceptible response to the system of planting sunflower as a whole or intercrop component with groundnut. However, leaves in the initial stages during both the summer seasons accumulated significantly higher amount of nitrogen in the

Table 12. Nitrogen uptake (mg per plant) by leaves of sunflower as influenced by different treatments

Treatment	Days after sowing (Summer) 30		45		60		75		90		Kharif 1983 30	45	60	75	90
	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984					
SNE	210.7	295.9	612.4	517.4	753.4	498.2	510.8	280.5	117.8	143.7	39.0	161.9	161.9	99.9	60.4
SNP	209.4	196.7	650.6	473.5	819.2	599.8	495.4	296.2	212.5	181.9	44.8	119.6	125.8	103.4	63.6
SWE	154.8	194.0	531.4	646.4	840.0	582.5	489.7	310.4	108.9	148.6	57.7	194.9	154.6	150.4	82.2
SWP	179.4	221.4	504.0	745.8	755.3	627.7	734.3	265.8	249.0	91.9	49.5	151.5	153.9	161.7	93.8
INE	142.4	238.6	590.7	540.8	948.5	614.7	450.9	306.9	103.6	136.7	27.7	96.0	127.2	115.8	77.4
INP	135.4	122.6	688.0	608.0	932.9	565.6	340.0	290.4	140.9	159.8	35.8	107.7	104.4	97.6	56.3
IWE	148.9	129.2	568.4	627.1	777.9	527.5	350.1	265.8	88.6	133.7	25.8	106.4	118.4	88.5	53.2
IWP	141.8	110.1	469.0	425.4	773.5	496.0	364.6	386.5	137.7	136.9	29.6	98.6	112.8	98.5	66.8
SE ±	42.0	70.6	130.0	155.4	210.4	118.5	174.2	64.8	73.2	74.0	19.8	12.0	18.4	46.2	39.0
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	25.7	39.5	NS	NS
Mean	165.4	188.6	576.8	573.1	825.09	564.0	467.0	300.3	144.9	141.7	38.7	129.6	132.4	114.5	69.2
S x M															
SN	210.1	246.3	631.5	495.5	786.3	549.0	503.1	288.4	165.2	162.8	41.9	140.7*	143.8	101.6	62.0
SW	167.1	207.7	517.7	696.1	797.7	605.1	612.0	288.1	179.0	120.3	53.6	173.2	154.2	156.0	88.0
IN	138.9	180.6	639.4	574.4	940.7	590.2	395.5	298.7	122.3	148.3	31.7	101.8	115.8	106.7	66.8
IW	145.4	119.7	518.7	526.3	775.7	511.8	357.4	326.2	113.2	135.3	27.7	102.5	115.6	93.5	60.0
S x P															
SE	182.8	245.0	571.9	581.9	796.7	540.4	500.3	295.5	113.4	146.2	48.3	178.4*	158.2	125.1	75.3
SP	194.4	209.1	574.6	609.7	787.3	613.8	614.9	281.0	230.8	136.9	47.1	135.5	139.8	132.5	78.7
IE	145.7	183.9	579.6	584.0	863.2	571.1	400.5	286.4	163.4	135.2	26.7	101.2	122.3	102.1	65.3
IP	138.6	116.4	578.5	516.7	853.2	530.8	352.3	338.5	139.3	148.4	32.7	103.1	108.6	98.0	80.3
M x P															
NE	176.6	267.3	601.6	529.1	851.0	556.5	480.9	293.7	110.7	140.2	33.3	128.9	144.5	107.8	72.9
NP	172.4	159.7	669.3	540.8	876.1	582.7	417.7	293.3	176.7	170.9	40.3	113.6	115.1	100.5	59.9
WE	151.9	161.6	549.9	636.8	809.0	555.0	419.9	288.1	98.8	141.2	41.7	150.6	136.5	119.4	67.7
WP	160.6	165.8	486.5	585.6	764.4	561.9	549.5	326.2	193.4	114.4	39.5	125.0	133.3	130.1	80.3
SE ±	30.0	49.2	91.0	109.4	151.2	83.4	124.3	45.2	51.0	53.2	14.2	8.6	13.1	33.0	27.9
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	18.4	NS	NS	NS
System															
S	188.6*	227.0*	574.6	595.8	792.0	577.1	557.6	288.2	172.1	141.5	47.7	157.0**	149.0*	128.8	77.0
I	142.1	150.1	579.0	550.3	858.2	551.0	376.4	312.4	117.7	141.8	29.7	102.2	115.7	100.1	63.4
Method															
N	174.5	213.5	635.4	534.9	863.5	569.6	449.3	293.5	143.7	155.5	36.8	121.3	129.8	104.2	66.4
W	156.2	163.7	518.2	611.2	786.7	558.4	484.7	307.1	146.1	127.8	40.6	137.8	134.9	124.8	74.0
Pattern															
E	164.2	214.4	575.7	582.9	830.0	555.7	450.4	290.9	104.7	140.7	37.5	139.8	140.5	113.6	224.2
P	166.5	163.7	577.9	563.2	820.2	572.3	483.6	309.7	185.0	142.6	39.9	119.3	124.2	115.3	70.1
SE ±	21.0	35.3	60.0	77.6	104.8	58.6	88.7	32.4	0.37	37.1	9.9	6.0	9.2	23.1	19.5
CD 5%	41.0	75.2	NS	NS	NS	NS	NS	NS	NS	NS	NS	12.9	19.7	NS	NS

sole crop treatment. In *kharif*, sunflower in intercrop system showed that the nitrogen uptake by the leaves was less than in sole crop throughout the growth stages. But the differences were significant at bud and flowering stages.

The method of planting in narrow/wide rows and the pattern of row arrangement had no significant influence on the nitrogen uptake at any stage in the three trials.

Planting system interacted significantly with planting method as well as planting pattern at bud stage in the *kharif* season.

b. Stem : The mean uptake of nitrogen in stem increased steadily with crop age until the maximum was reached at flowering and then declined towards maturity (Table 13). Initially, the stem removed 38.7, 44.0 and 8.2 mg N $plant^{-1}$ during the vegetative phase (30 days). The maximum uptake at flowering was of the order of 412.2, 295.5 and 92.8 mg N $plant^{-1}$. The uptake of soil nitrogen then practically ceased and declined to 178.1, 133.9 and 64.5 mg $plant^{-1}$ at harvest in the summer seasons during 1983, 1984 and in *kharif* 1983 respectively.

Planting sunflower in solid rows or intercropped with groundnut did not show a remarkable variation in the amount

Table 13. Nitrogen uptake (mg per plant) by stem of sunflower as influenced by different treatments

Treat- ment	Days after sowing														
	30		45		60		75		90		30	45	60	75	90
	Summer										Kharif				
	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984	1983				
SNE	45.9	51.9	200.4	278.2	477.2	287.9	231.9	202.0	215.7	148.4	6.5	41.3	95.0	76.1	60.8
SNP	46.9	58.2	168.2	272.3	384.7	318.2	267.2	209.8	216.0	135.6	9.0	27.2	99.6	75.1	66.9
SWE	33.4	44.2	151.9	180.0	475.8	265.6	213.3	199.0	168.8	144.5	9.7	45.3	102.0	124.8	90.5
SWP	34.2	56.3	204.0	232.6	324.8	320.9	248.4	229.8	134.4	114.0	13.3	44.5	82.7	122.4	68.3
INE	39.1	59.2	237.0	235.2	483.3	336.0	203.1	195.2	167.3	138.2	6.2	29.5	104.6	79.0	69.3
INP	47.2	27.5	192.9	127.8	380.2	295.6	193.1	238.1	178.7	131.0	6.9	22.0	90.2	56.6	53.7
IWE	44.41	29.5	159.9	141.2	420.2	283.8	214.1	195.8	194.0	131.5	7.6	31.4	112.8	78.7	66.6
IWP	36.4	25.4	158.0	172.0	351.2	253.0	210.7	231.9	149.8	127.8	6.3	25.3	55.3	83.3	40.1
SE ±	21.0	16.2	74.0	76.0	142.6	87.5	54.0	72.0	84.2	51.0	4.2	18.0	39.5	48.0	31.4
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean	38.7	44.0	184.0	193.2	412.2	295.5	222.7	212.7	178.1	133.9	8.2	33.3	92.8	87.0	64.5
S X M															
SN	46.4	55.1	184.3	275.3	431.0	303.1	249.6	205.9	215.9	142.0	7.7	34.2	97.3	75.6	63.8
SW	33.8	51.7	178.0	206.3	400.3	293.3	230.9	214.4	151.6	129.3	11.5	44.9	92.3	123.6	79.4
IN	43.2	44.4	215.0	181.5	431.8	315.8	198.1	216.7	173.0	134.6	6.5	33.6	97.4	67.8	61.5
IW	40.3	27.5	159.0	156.6	385.7	269.9	212.4	213.9	171.9	129.7	6.9	28.3	84.0	81.0	53.3
S x P															
SE	39.7	48.1	176.2	229.1	476.5	276.8	222.6	200.5	192.3	146.5	8.1	43.3	98.5	100.4	75.6
SP	40.6	57.3	186.1	252.5	354.8	319.6	257.8	219.8	175.2	124.8	11.1	35.8	91.1	98.7	67.6
IE	41.6	44.4	198.5	188.2	451.8	311.4	208.6	195.5	180.7	134.9	6.9	30.4	108.7	78.6	67.9
IP	41.8	26.5	175.5	149.9	365.7	274.3	201.9	235.0	164.3	129.4	6.6	23.6	72.7	69.9	46.9
M x P															
NE	42.5	55.6	218.7	256.7	480.3	312.0	217.5	198.6	191.5	143.3	6.3	35.4	99.8	77.5	65.0
NP	47.1	42.9	180.6	200.1	382.5	306.9	230.2	224.0	197.4	133.3	7.9	24.6	94.9	65.8	60.3
WE	38.8	36.9	155.9	160.6	448.0	276.2	213.7	197.4	181.4	138.0	8.6	38.3	107.4	101.7	78.5
WP	35.3	40.9	181.0	202.3	338.0	287.0	229.6	230.9	142.1	120.9	9.8	34.9	69.0	102.8	54.2
SE ±	14.2	11.4	51.0	49.2	108.4	61.4	38.6	49.3	51.4	32.0	3.0	12.9	28.2	34.3	22.4
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
System															
S	40.1	52.7	181.1	240.8	415.6	298.2	240.2	210.2	183.7	135.6	9.6	39.6	94.8	99.6	71.6
I	41.7	35.4	187.0	169.1	408.7	292.0	205.3	215.3	172.5	132.1	6.7	27.0	90.7	74.4	57.4
Method															
N	44.8	49.2	199.6	228.4	431.4	309.4	223.8	211.3	194.4	138.3	7.1	30.0	97.3	71.7	65.0
W	37.0	38.9	168.5	181.5	393.0	281.6	221.6	214.1	161.8	129.5	9.2	36.6	88.2	102.3	66.4
Pattern															
E	40.6	46.2	187.3	208.7	464.1	294.1	215.6	198.0	186.5	140.7	7.5	36.9	103.6	89.6	71.8
P	41.2	41.9	180.8	201.2	360.2	296.9	229.9	227.4	169.7	127.1	8.9	29.7	81.9	84.3	57.2
SE ±	10.5	8.0	37.0	36.0	71.3	43.7	27.0	36.0	42.1	25.0	2.1	9.0	19.8	24.0	15.7
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

of nitrogen removed by the stem per plant in any season. Though the uptake in sole crop treatment in general was slightly better particularly in the <u>kharif</u> season, the differences were not significant.

Response to a change in the row width was not apparent at any stage and consequently no significant differences were observed.

Nitrogen accumulation in the stem did not change appreciably whether the rows were arranged in an equidistant or paired row pattern. The slightly differential and inconsistent response was not significant.

The effects of interactions were not marked to critically vary the response of nitrogen uptake.

c. **Capitulum:** The mean uptake of nitrogen increased enormously with the flattening and development of flower buds (30.3, 86.9 and 13.6 mg N $plant^{-1}$) to a capitulum till maturity (680.5, 715.1 and 210.9 mg N $plant^{-1}$). In the summer season during 1983, the uptake followed a decline at seed filling stage before it reached the maximum at harvest (Table 14).

Nitrogen uptake in sunflower associated with groundnut was significantly less than the monoculture at bud stage in the summer season and at harvest in <u>kharif</u> during 1984 and

Table 14. Nitrogen uptake (mg per plant) by the capitulum of sunflower as influenced by different treatments

Treat-ment	Summer 45 DAS 1983	Summer 45 DAS 1984	Summer 60 DAS 1983	Summer 60 DAS 1984	Summer 75 DAS 1983	Summer 75 DAS 1984	Summer 90 DAS 1983	Summer 90 DAS 1984	Kharif 1983 45	Kharif 1983 60	Kharif 1983 75	Kharif 1983 90
SNE	17.0	105.2	500.2	563.2	420.4	647.6	580.1	788.0	15.7	39.7	140.0	195.4
SNP	30.2	119.4	566.6	580.7	341.5	695.6	720.8	712.3	11.6	36.5	119.5	211.1
SWE	38.8	87.0	525.6	544.4	390.6	541.2	601.4	626.5	12.9	41.2	168.8	278.8
SWP	47.2	116.1	568.1	344.5	335.6	519.0	784.9	757.9	13.3	53.8	165.3	250.0
INE	28.4	126.8	503.8	556.8	395.4	554.4	753.2	647.9	18.1	40.4	130.3	195.2
INP	28.6	47.5	534.0	519.0	380.7	558.0	661.8	666.5	9.8	41.0	90.7	207.0
IWE	28.8	51.3	625.2	506.2	311.5	567.6	633.4	774.7	10.3	42.6	92.0	166.9
IWP	29.4	42.3	573.2	569.8	377.0	642.6	708.1	747.0	17.6	45.5	120.0	183.1
SE ±	7.6	22.0	246.0	230.4	146.0	202.0	234.0	326.0	6.4	21.0	46.0	40.0
CD 5%	NS	47.1	NS	NS	NS	NS	NS	NS	NS	NS	NS	80.8
Mean	30.3	86.9	549.5	523.1	369.1	590.7	680.5	715.1	13.6	42.6	128.3	210.9
S x M												
SN	23.6	112.3*	533.3	571.9	380.9	671.6	650.4	750.1	13.6	38.1	129.7	203.2
SW	43.0	101.5	546.8	444.4	363.1	530.1	693.1	692.2	13.1	47.5	167.0	264.4
IN	28.5	87.1	518.9	537.9	388.0	556.2	707.5	657.2	13.9	40.7	110.5	201.1
IW	29.1	46.8	599.2	538.0	344.2	605.1	670.7	760.8	13.9	44.0	106.0	175.0
S x P												
SE	27.9	96.1*	512.8	553.8	405.5	594.4	590.7	707.2	14.3	40.4	154.4	237.1
SP	38.7	117.1	567.3	462.3	338.5	607.3	752.8	735.1	12.4	45.1	142.4	230.5
IE	28.6	89.0	564.5	531.5	353.4	561.0	693.3	711.3	14.2	41.5	111.1	181.0
IP	29.0	44.9	553.6	544.4	378.8	600.3	684.9	706.7	13.7	43.2	105.3	195.0
M x P												
NE	22.7	116.0	501.9	560.0	407.9	601.0	666.6	717.9	16.9	40.0	135.1	195.3
NP	29.4	83.4	550.3	549.8	361.1	626.8	691.3	689.4	10.7	38.7	105.1	209.0
WE	33.8	69.1	575.4	525.3	351.0	554.4	617.4	700.6	11.6	41.9	130.4	222.8
WP	38.3	79.2	570.6	457.1	356.3	580.8	746.5	752.4	15.4	49.6	142.6	216.5
SE ±	5.4	15.7	175.7	164.6	104.0	144.3	167.0	232.8	4.6	15.0	32.9	28.4
CD 5%	NS	33.7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
System												
S	33.3	106.9*	540.1	508.2	372.0	600.8	671.8	721.2	13.4	42.8	148.4	233.8 *
I	28.8	66.9	559.0	537.9	366.1	580.6	689.1	709.0	13.9	42.4	108.2	188.0
Method												
N	26.0	99.7	526.1	554.9	384.5	613.9	679.0	703.7	13.8	39.4	120.1	202.1
W	36.0	74.2	573.0	491.2	353.7	567.6	681.9	726.5	13.5	45.8	136.5	219.7
Pattern												
E	28.2	92.6	538.6	542.6	379.5	577.7	642.0	709.3	14.2	40.9	132.8	209.1
P	33.8	81.3	560.5	503.5	358.7	603.8	718.9	720.9	13.1	44.2	123.9	212.8
SE ±	3.8	11.0	123.0	115.2	73.0	101.0	117.0	163.0	3.2	10.5	23.0	20.0
CD 5%	NS	23.6	NS	NS	NS	NS	NS	NS	NS	NS	NS	42.9

1983 respectively. The uptake pattern at all other stages did not follow a regular trend and did not differ significantly by the planting system.

Neither the differences in row width nor the planting pattern were critical to vary the nutrient uptake significantly in any season. The capitulum accumulated approximately similar amount of nitrogen within each comparison with no marked differences.

None of the interactions had a positive influence on the nitrogen uptake except that the planting system interacted significantly with the planting method and also with the planting pattern at 30 days during summer, 1984.

4.1.2.2.2 **Phosphorus**

a. **Leaves** : Like nitrogen the absorption of phosphorus increased with crop age upto flowering in the summer seasons but continued to increase further upto the seed filling stage in *kharif* (Table 15).

The mean uptake of phosphorus at the vegetative phase (30 days) increased progressively from 9.2 and 8.2 mg plant^{-1} in the summer seasons during 1983 and 1984 respectively to 78.8 and 47.5 mg plant^{-1} at flowering. In *kharif*, the uptake in general was relatively too low and increased from an initial uptake of 3.8 mg plant^{-1} at 30 days to 26.1 mg plant^{-1} at seed filling. Phosphorus in the leaves then reduced drastically diminishing to 13.7 and 9.37 mg plant^{-1} in the summer seasons during 1983 and 1984 and to 8.4 mg plant^{-1} in *kharif* during 1983.

Table 15. Phosphorus uptake (mg per plant) by the leaves of sunflower as influenced by different treatments

Treat-ment	Summer 30 DAS 1983	Summer 30 DAS 1984	Summer 45 DAS 1983	Summer 45 DAS 1984	Summer 60 DAS 1983	Summer 60 DAS 1984	Summer 75 DAS 1983	Summer 75 DAS 1984	Summer 90 DAS 1983	Summer 90 DAS 1984	Kharif 1983 30 DAS	Kharif 1983 45 DAS	Kharif 1983 60 DAS	Kharif 1983 75 DAS	Kharif 1983 90 DAS
SNE	11.0	12.8	44.6	35.2	78.8	37.0	73.3	30.1	14.7	10.7	3.4	22.3	28.6	24.2	7.4
SNP	11.2	8.7	37.7	26.1	71.2	52.2	84.2	31.7	18.1	11.9	4.4	15.7	21.6	22.5	6.1
SWE	8.0	8.2	39.9	35.1	84.0	43.7	83.1	32.2	9.7	9.6	6.3	30.6	31.4	38.5	10.5
SWP	10.5	10.3	44.1	43.2	77.6	55.3	81.3	30.2	16.9	6.4	4.9	17.8	25.3	36.0	12.2
INE	8.4	9.9	40.5	30.4	83.0	51.2	59.3	36.0	14.2	7.7	3.1	12.7	23.4	26.1	8.5
INP	8.0	5.7	42.4	32.9	81.3	46.9	53.6	35.2	13.6	12.0	3.2	13.2	17.8	20.7	7.9
IWE	6.5	5.3	37.7	37.3	75.8	48.5	56.2	31.3	8.2	8.8	2.6	13.9	18.8	20.9	7.8
IWP	8.3	4.7	36.5	27.3	79.4	44.9	62.2	42.4	14.4	7.9	2.8	11.6	19.0	20.5	7.2
SE ±	4.0	2.8	18.0	10.8	21.0	9.7	26.0	9.4	4.2	3.6	1.6	7.6	8.4	8.6	4.2
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	16.3	NS	NS	NS
Mean	9.2	8.2	40.4	33.4	78.8	47.5	69.1	33.6	13.7	9.37	3.8	17.2	23.2	26.1	8.4
S x M															
SN	11.1	10.7	41.1	30.6	75.0	44.6	78.7	30.9	16.4	11.3	3.9	30.1	25.1	23.3	6.7
SW	9.2	9.2	42.0	39.1	80.8	49.5	82.2	31.2	13.3	8.0	5.6	24.2	28.3	37.2	11.3
IN	8.2	7.8	41.4	31.6	82.1	49.0	56.4	35.6	13.9	9.8	3.1	12.9	20.6	23.4	8.2
IW	8.4	5.0	37.1	32.3	77.6	46.7	59.2	36.8	11.3	8.3	2.7	12.7	18.9	20.7	7.5
S x P															
SE	9.5	10.5	40.6	35.1	81.4	40.3	78.2	31.1	12.2	10.1	4.8	26.4	30.0	31.3	8.9
SP	10.8	9.5	40.2	34.6	74.4	53.7	82.7	30.9	17.5	9.1	4.6	16.7	23.4	29.2	9.1
IE	8.4	7.6	38.5	33.8	79.4	49.8	57.7	33.6	11.2	8.2	2.8	13.3	21.1	23.5	8.1
IP	8.1	5.2	39.4	30.1	80.3	50.1	57.9	36.3	14.0	9.9	3.0	12.4	18.4	20.6	7.5
M x P															
NE	9.7	11.3	42.5	32.8	80.9	44.1	66.3	33.0	14.4	9.2	3.2	17.5	26.0	25.1	7.9
NP	9.6	7.2	40.0	29.5	76.2	49.5	68.9	33.4	15.8	11.9	3.8	14.4	19.7	21.6	7.0
WE	8.2	6.7	38.8	36.2	79.9	46.1	69.7	31.7	8.9	9.2	4.4	22.2	25.1	29.7	9.1
WP	9.4	7.5	40.3	35.2	78.5	50.1	71.7	36.3	15.6	7.1	3.8	14.7	22.1	28.2	9.7
SE ±	.2.7	2.0	12.8	7.7	15.0	6.9	18.6	6.7	2.7	2.5	1.1	5.4	6.0	6.1	3.0
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
System															
S	10.2	10.0*	41.6	34.9	77.9	47.0	80.5	31.0	14.8	9.6	4.7	21.6*	26.7	30.3	9.0
I	8.3	6.4	39.3	32.0	79.9	47.9	57.8	36.2	12.6	9.1	2.9	12.8	19.7	22.0	7.8
Method															
N	9.6	9.3	41.3	31.1	78.5	46.8	67.6	33.2	15.1	10.6	3.5	16.0	22.8	23.3	7.5
W	8.8	7.2	39.5	35.7	79.2	45.1	70.7	34.0	12.3	8.2	4.1	18.5	23.6	28.9	9.4
Pattern															
E	8.9	9.0	40.7	34.5	80.4	45.1	68.0	32.4	11.7	9.2	3.8	19.9	25.5	27.4	8.5
P	9.5	7.3	40.2	32.4	77.4	49.8	70.3	34.9	15.7	9.5	3.8	14.5	20.9	24.9	8.3
SE ±	2.0	1.4	9.0	5.4	10.5	4.8	13.0	4.7	2.1	1.8	0.8	3.8	4.2	4.3	2.1
CD 5%	NS	3.0	NS	NS	NS	NS	NS	NS	NS	NS	NS	8.2	NS	NS	NS

Phosphorus uptake by sunflower associated with groundnut did match the monoculture, though the uptake was slightly reduced at most instances in the summer seasons and at every sampling in kharif. However, the differences were barely significant at bud stage in the kharif season during 1983 and at vegetative stage in the summer season during 1984. None of the comparisons were critically different at any other stage.

Analysis of variance to detect the variable response of sunflower to row widths or the pattern of row arrangement showed no significant change in the quantity of phosphorus removed by the leaves. Despite, the lack of response to planting method, wider rows tended to perform better than the narrow rows in the kharif season. The removal of phosphorus in equidistant rows also appeared marginally better than the paired rows in this season. The trend of variation for the method or pattern of planting was not regular in the summer seasons.

None of the interactions were significant in the three seasons.

b. **Stem** : The pattern of phosphorus accumulation in the stem over different developmental stages of sunflower was similar as in the leaves (Table 16).

The mean uptake increased profoundly from the initial samplings at the vegetative stage (2.6 and 1.8 mg plant^{-1}) during each successive year in 1983 and 1984 to a maximum at flowering (81.8 and 53.3 mg P plant^{-1}) in the summer seasons.

Table 16. Phosphorus uptake (mg per plant) by the stem of sunflower as influenced by different treatments

Treatment	Summer 30 DAS 1983	Summer 30 DAS 1984	Summer 45 DAS 1983	Summer 45 DAS 1984	Summer 60 DAS 1983	Summer 60 DAS 1984	Summer 75 DAS 1983	Summer 75 DAS 1984	Summer 90 DAS 1983	Summer 90 DAS 1984	Kharif 1983 30	Kharif 1983 45	Kharif 1983 60	Kharif 1983 75	Kharif 1983 90
SNE	3.2	2.3	20.1	23.8	75.5	47.6	55.9	37.8	31.1	7.8	0.6	6.6	28.2	27.3	11.7
SNP	2.9	2.2	19.2	19.8	101.1	58.4	68.2	38.5	22.3	7.7	0.9	4.5	27.1	31.1	12.5
SWE	2.1	1.8	14.9	15.9	80.9	48.1	52.7	38.9	21.9	9.5	1.0	7.7	30.1	46.6	13.4
SWP	2.3	2.3	18.8	21.6	78.3	63.0	65.0	47.9	27.9	10.3	1.2	5.9	26.0	26.9	13.7
INE	2.7	2.5	27.8	19.0	83.4	54.5	48.1	41.2	16.7	7.5	0.5	3.8	28.2	28.5	13.6
INP	2.9	1.2	20.3	12.6	77.7	54.2	44.9	44.4	20.5	9.6	0.6	3.6	24.2	21.2	10.7
IWE	2.5	1.2	17.2	10.0	74.0	58.9	57.7	42.5	27.4	10.0	0.5	4.4	26.6	19.0	14.1
IWP	2.4	1.1	15.4	14.1	83.6	42.1	49.2	41.2	23.6	9.5	0.6	3.5	20.6	30.3	11.7
SE ±	1.6	0.8	12.0	5.1	24.0	12.4	22.0	7.5	19.0	6.0	0.4	2.4	18.0	7.0	6.4
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean	2.6	1.8	19.2	17.1	81.8	53.3	55.2	41.5	23.9	7.9	0.7	5.0	26.4	30.1	24.7
S x M															
SN	3.0	2.2	19.6	21.8	88.3	53.0	62.0	38.1	26.7	7.7	0.7	5.5	27.6	29.2	12.1
SW	2.2	2.0	16.8	18.7	79.6	55.5	58.8	43.4	24.9	9.9	1.1	6.8	28.0	41.7	13.5
IN	2.8	1.8	24.1	15.8	80.5	54.3	46.5	42.8	18.6	8.5	0.5	3.7	26.2	24.8	12.1
IW	2.4	1.1	16.3	12.0	78.8	50.5	53.4	41.8	25.5	9.7	0.5	3.9	23.6	24.6	12.9
S x P															
SE	2.6	2.0	17.5	19.8	78.2	47.8	54.3	38.3	26.5	8.6	0.8	7.1	29.1	36.9	12.5
SP	2.6	2.2	19.0	20.7	89.7	60.7	66.6	43.2	25.1	9.0	1.0	5.2	26.5	34.0	13.1
IE	2.6	1.8	22.5	14.5	78.7	56.7	52.9	41.8	22.0	8.7	0.5	4.1	27.4	23.7	13.8
IP	2.6	1.1	17.8	13.3	80.6	48.1	47.0	42.8	22.0	9.5	0.6	3.5	22.4	25.7	11.2
M x P															
NE	2.9	2.4	24.0	21.4	79.4	51.0	52.0	39.5	26.5	7.6	0.5	5.2	28.2	27.9	12.6
NP	2.9	1.7	19.7	16.2	89.4	56.3	56.5	41.4	25.1	8.6	0.7	4.0	25.6	26.1	11.6
WE	2.3	1.5	16.0	12.9	77.4	53.5	55.2	40.7	24.6	9.7	0.7	6.0	28.3	32.8	13.7
WP	2.3	1.7	17.1	17.8	40.5	52.5	57.1	44.5	25.7	9.9	0.9	4.7	23.3	33.6	12.7
SE ±	1.1	0.6	8.6	3.6	17.1	8.7	15.7	5.3	13.6	4.2	0.3	1.7	12.9	5.0	4.6
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
System															
S	2.6	2.1	18.2	20.3	83.9	54.3	60.4	40.8	25.8	8.8	0.9	6.2	27.8	35.5	12.8
I	2.6	1.5	20.2	13.9	79.7	52.4	50.0	42.3	22.0	9.1	0.5	3.8	24.9	24.7	12.5
Method															
N	2.9	2.0	21.9	18.8	84.4	53.7	54.3	40.5	22.6	8.1	0.6	4.6	26.9	27.0	12.1
W	2.3	1.6	16.6	15.4	79.2	53.0	56.1	42.6	25.2	9.8	0.8	5.4	25.8	33.2	13.2
Pattern															
E	2.6	1.9	20.0	17.2	78.4	52.3	53.6	40.1	24.3	8.7	0.6	5.6	28.3	30.3	13.2
P	2.6	1.7	18.4	17.0	85.2	54.4	56.8	43.0	23.6	9.3	0.8	4.4	24.5	29.9	12.1
SE ±	0.8	0.4	6.0	2.6	12.0	6.2	11.0	3.7	9.5	3.0	0.2	1.2	9.0	3.5	3.2
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

In *kharif*, it increased from 0.7 mg $plant^{-1}$ at 30 days to 30.1 mg $plant^{-1}$ at seed filling stage. The uptake ceased after attaining the peak and declined at maturity.

Sole crop of sunflower accumulated slightly higher proportion of phosphorus throughout the growth stages in *kharif* and in most instances during the summer seasons. But, the associated growth of groundnut was not a serious deterrant to significantly vary the phosphorus accumulation in the stem of sunflower.

A change in the method of planting sunflower in wider rows in contrast to the narrow row width was not accompanied by a significant change in the uptake of phosphorus. The pattern of row arrangement, similarly, indicated that the amount of phosphorus removed was identical in rows that were paired or not.

The interactions both at the first order and higher order had no profound influence on the phosphorus uptake.

c. **Capitulum** : The mean uptake of phosphorus increased consistently from bud formation (3.8, 5.0 and 3.2 mg P $plant^{-1}$) till the heads were physiologically mature (168.2, 140.8 and 95.0 mg P $plant^{-1}$) in the summer seasons during 1983, 1984 and *kharif*, 1983. The influence of different treatments was not perceptible in any season (Table 17).

Planting system indicated that the sole crop in general had a modest over-riding effect. However, the competitive effect of groundnut was mitigated bringing into greater

Table 17. Phosphorus uptake (mg per plant) by the capitulum of sunflower as influenced by different treatments

Treatment	Summer 45 DAS 1983	Summer 45 DAS 1984	Summer 60 DAS 1983	Summer 60 DAS 1984	Summer 75 DAS 1983	Summer 75 DAS 1984	Summer 90 DAS 1983	Summer 90 DAS 1984	Kharif 1983 45 DAS	Kharif 1983 60 DAS	Kharif 1983 75 DAS	Kharif 1983 90 DAS
SNE	2.5	5.8	92.2	75.6	111.8	112.1	153.2	168.4	3.6	13.1	51.2	94.4
SNP	3.3	6.7	99.1	80.9	123.4	107.3	177.6	154.8	3.2	13.6	47.3	92.4
SWE	4.9	5.3	102.2	82.2	113.4	89.7	160.2	124.3	3.2	13.2	63.9	118.4
SWP	5.6	6.5	92.2	65.3	80.9	90.0	210.9	137.4	3.2	18.8	78.6	106.1
INE	3.5	7.7	97.4	83.6	126.4	78.4	187.0	111.8	3.7	12.1	47.7	89.9
INP	3.6	2.7	112.6	75.9	101.2	86.8	141.5	139.1	2.6	12.2	33.3	92.5
IWE	3.4	3.1	110.9	77.4	115.9	95.7	141.9	149.1	2.4	13.1	39.9	80.2
IWP	3.4	2.2	101.8	85.8	119.6	98.6	173.5	141.5	4.1	13.8	39.0	86.5
SE ±	2.6	1.8	42.0	21.2	58.0	32.0	54.0	4.8	1.8	6.0	24.0	26.2
CD 5%	NS	3.8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean	3.8	5.0	101.0	78.3	111.6	94.8	168.2	140.8	3.2	13.7	50.1	95.0
S X M												
SN	2.9	6.2*	95.6	78.2	117.6	109.7	165.4	161.6	3.4	13.3	49.2	93.4
SW	5.2	5.9	97.2	73.7	97.1	89.8	185.5	130.8	3.2	16.0	71.2	112.2
IN	3.5	5.2	105.0	79.7	113.8	82.6	164.2	125.4	3.1	12.1	40.5	91.2
IW	3.4	2.6	106.3	80.1	117.7	97.1	157.7	145.3	3.2	13.4	39.4	83.3
S X P												
SE	3.7	5.5	97.2	78.9	112.5	100.9	156.7	146.3	3.4	13.1	57.5	106.4
SP	4.4	6.6	95.6	73.1	102.1	98.6	194.2	146.1	3.2	16.2	62.9	99.2
IE	3.4	5.4	104.1	80.5	121.1	87.0	164.4	130.4	3.0	12.6	43.8	85.0
IP	3.5	2.4	107.2	80.8	110.4	92.7	157.5	140.3	3.3	16.3	36.1	89.5
M X P												
NE	3.0	6.7	94.8	79.6	119.1	95.2	170.1	140.1	3.6	12.6	49.4	92.1
NP	3.4	4.7	105.8	78.4	112.3	97.0	159.5	146.9	2.9	12.9	40.3	92.4
WE	4.1	4.2	106.5	79.8	114.6	92.7	151.0	136.7	2.8	13.1	51.9	99.3
WP	4.5	4.3	97.0	75.5	100.2	94.3	192.2	139.4	3.6	16.3	58.8	96.3
SE ±	1.8	1.3	30.0	15.1	41.3	22.8	38.5	3.4	1.3	4.3	17.1	18.7
CD 5%	NS	2.7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
System.												
S	4.1	6.1*	96.4	76.0	107.3	99.7	175.5	147.1	3.3	14.7	60.2	102.8
I	3.5	3.9	105.6	80.7	115.8	89.8	161.0	135.4	3.2	12.8	39.9	87.3
Method												
N	3.2	5.7	100.3	79.0	115.7	96.1	164.8	143.5	3.3	12.7	44.9	92.3
W	4.3	4.3	101.8	77.7	107.4	93.5	171.6	138.1	3.2	14.7	55.3	97.8
Pattern												
E	3.6	5.5	100.7	79.7	116.9	94.0	160.6	138.4	3.2	12.9	50.7	95.7
P	3.9	4.5	101.4	77.0	106.3	95.7	175.9	143.2	3.3	14.6	49.5	94.4
SE ±	1.3	0.9	21.0	10.6	2.9	16.0	27.0	2.4	0.9	3.0	12.0	13.1
CD 5%	NS	1.9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

prominence, statistically similar amount of phosphorus removed by the associated sunflower as in the pure stand. The only significant effect was observed at bud stage during summer, 1984.

The effect of planting method to varied row widths on the accumulation of phosphorus in capitulum was not perspicuous and significant.

Similarly, no remarkable variation in response to the uptake of phosphorus in the capitulum could be detected in the analysis of variance for the rows spaced uniformly or paired.

The treatment effects were all independent and did not interact to cause a significant variation in their response to uptake of phosphorus except for a significant interaction between method and planting pattern only at bud stage during summer, 1984.

4.1.2.2.3 Potassium

a. **Leaf** : Removal of potassium followed a similar trend of increasing to a maximum with crop age and declining prior to maturity like nitrogen and phosphorus (Table 18).

The mean uptake of potassium in leaves increased from 76.3 and 27.6 mg plant^{-1} in the summer and kharif season during 1983 at the vegetative phase to a maximum of 757.9 and 192.8 mg plant^{-1} at seed filling stage. The maximum uptake during summer, 1984 was attained at the flowering phase. The mean uptake in this season increased from 81.9 mg plant^{-1} at

Table 16. Potassium uptake (mg per plant) in leaves of sunflower as influenced by different treatments

Treat-ment	Days after sowing														
	30		45		60		75		90		30	45	60	75	90
	Summer										Kharif				
	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984	1983				
SNE	84.5	124.3	231.6	192.2	440.2	393.5	824.2	338.3	330.3	275.8	25.4	89.4	163.3	175.7	118.1
SNP	99.7	85.0	206.1	189.7	547.6	524.6	966.0	313.3	493.8	398.2	33.0	66.1	119.7	159.7	132.3
SWE	65.3	88.1	189.6	221.8	595.2	544.7	942.5	368.4	222.3	310.0	44.3	113.4	160.5	246.8	172.9
SWP	86.0	103.5	246.4	251.8	579.6	470.1	928.9	299.5	510.8	203.6	35.4	76.6	143.6	271.5	169.7
INE	71.8	101.5	170.8	174.1	666.7	534.8	613.6	356.0	387.1	254.1	21.2	54.4	123.3	205.5	151.0
INP	67.9	51.8	228.4	182.6	586.0	493.2	577.9	336.4	321.8	339.2	23.3	58.3	107.9	157.8	123.5
IWE	65.8	53.4	220.9	228.1	543.9	493.1	538.0	298.3	210.7	244.8	17.3	64.3	110.7	161.4	111.5
IWP	69.7	47.6	225.6	148.5	540.4	400.7	672.3	399.6	366.9	235.1	21.0	52.4	109.8	164.0	132.8
SE ±	38.1	26.4	52.0	91.0	154.8	116.3	231.8	50.6	183.4	112.0	9.9	41.0	74.2	94.0	96.0
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean	76.3	81.9	214.9	198.6	562.4	481.9	757.9	338.7	355.5	282.6	27.6	71.8	129.8	192.8	139.0
S x M															
SN	92.1	104.7	218.9	191.0	493.9	459.2	895.1	325.8	412.1	337.0	34.8	101.4	161.9	211.2	145.5
SW	75.7	95.8	218.0	236.7	587.4	507.4	935.7	334.0	366.6	256.8	34.2	71.3	131.6	215.6	151.0
IN	69.9	76.7	199.6	178.4	626.4	514.0	595.8	346.2	354.5	296.7	19.2	59.3	117.0	183.4	131.2
IW	67.8	50.5	223.3	188.3	542.2	445.9	605.2	349.0	288.8	240.0	22.1	55.3	108.8	160.9	151.2
S x P															
SE	74.9	106.2	210.6	206.7	517.7	469.3	883.4	353.4	276.3	292.9	34.8	101.4	161.9	211.2	145.5
SP	92.9	94.3	226.3	220.8	563.6	497.4	947.5	306.4	502.3	300.9	34.2	71.3	131.6	215.6	151.0
IE	68.8	77.5	195.9	201.1	605.3	514.0	575.8	327.2	298.9	249.5	19.2	59.3	117.0	183.4	131.2
IP	68.8	49.7	227.0	165.6	563.2	447.0	625.1	368.0	344.4	287.2	22.1	55.3	108.8	160.9	151.2
M x P															
NE	78.2	112.9	201.2	183.2	553.5	464.3	718.9	347.2	358.7	265.0	23.3	71.9	143.3	190.6	134.5
NP	83.8	68.4	217.3	186.2	566.8	508.9	772.0	324.9	407.8	368.7	28.1	62.2	113.8	158.7	141.6
WE	65.6	70.8	205.3	224.9	569.6	518.9	740.3	333.4	216.5	323.1	30.8	88.8	135.6	204.1	142.2
WP	77.9	75.5	236.0	200.2	560.0	435.4	800.6	349.6	438.9	219.4	28.2	64.5	126.7	217.7	151.2
SE ±	26.2	18.2	36.4	65.3	116.2	82.1	164.5	35.0	126.5	79.4	7.1	29.3	53.0	67.1	68.6
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
System															
S	83.9	100.2*	218.4	213.8	540.7	483.3	915.4	329.9	389.3	296.9	34.5	86.3	146.8	213.4	148.2
I	68.8	63.6	211.4	183.3	584.3	480.5	600.5	347.6	321.6	268.3	20.7	57.3	112.9	172.2	129.7
Method															
N	81.0	90.7	209.2	184.7	560.1	486.6	745.4	336.0	383.3	316.8	25.7	67.0	128.5	174.7	131.2
W	71.7	73.1	220.6	212.5	564.8	477.2	770.4	341.5	327.7	248.4	29.5	76.6	131.1	210.9	146.7
Pattern															
E	71.9	91.8	203.2	204.0	561.5	491.6	729.6	340.3	287.6	271.2	27.0	80.4	139.4	197.3	138.4
P	80.8	72.0	226.0	203.4	563.4	472.2	786.3	337.2	423.3	294.0	28.2	63.3	120.2	188.2	139.6
SE ±	19.0	13.2	26.0	46.0	77.4	58.1	115.9	25.3	91.7	56.0	5.0	20.0	37.1	47.0	48.0
CD 5%	NS	28.1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

30 days to 481.9 mg plant^{-1} at the flowering stage. The uptake values waned after the peak was attained to 355.5 and 282.6 mg plant^{-1} at harvest in the summer seasons and to 139.0 mg plant^{-1} in kharif.

The impact of planting system had no marked influence on the uptake of potassium by the leaves. Sole crop removed higher amount of potassium at all the phenological stages during kharif, 1983. But this trend was not apparent in the summer seasons. Nevertheless, the differences were not significant except at the vegetative phase during summer 1984.

The method of planting likewise presented an over-riding influence of the wider rows during kharif, 1983. While, no regular trend occured in the summer seasons. However, uptake of potassium did not differ significantly with a changed row spacing in any season.

Response to planting pattern did not show any significant trend of variation in the uptake of potassium by the leaves in an equidistant or paired row treatment irrespective of the growing season. Further, the uptake was free of interaction effects throughout the samplings.

b. **Stem** : Accumulation of potassium in the stem increased progressively upto seed filling followed by a sharp decline at harvest (Table 19). The mean uptake increased from 34.3 and 35.2 mg plant^{-1} during summer 1983 and 1984 and from 10.8 mg plant^{-1} during kharif, 1983 at 30 days to a maximum of 911.9, 784.8 and 476.5 mg plant^{-1} at seed filling stage during the corresponding seasons.

Table 19. Potassium uptake (mg per plant) by the stem of sunflower as influenced by different treatments

Treatment	Days after sowing														
	30		45		60		75		90		30	45	60	75	90
	Summer										Kharif				
	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984	1983				
SNE	36.8	39.2	97.9	168.6	506.8	417.1	1020.7	765.0	878.5	636.6	8.6	41.0	202.4	420.9	343.4
SNP	42.5	48.2	117.2	129.5	639.0	653.8	978.0	817.7	799.5	576.5	11.9	28.8	202.7	444.2	434.6
SWE	27.5	35.2	106.5	105.0	575.4	496.9	842.6	742.0	710.2	644.4	12.7	42.2	214.1	648.0	531.0
SWP	32.0	45.3	92.5	122.0	556.8	526.6	1162.1	765.1	836.9	499.4	18.2	44.8	209.7	647.0	428.6
INE	30.6	48.0	107.6	159.0	523.6	631.1	732.9	739.6	675.4	629.2	8.5	31.8	240.4	446.8	391.4
INP	41.4	21.4	113.3	68.4	561.6	608.4	720.6	850.2	667.6	599.3	7.5	22.0	181.9	258.2	370.1
IWE	34.3	23.0	100.6	78.5	494.2	599.3	757.9	769.0	739.4	621.8	10.2	30.5	242.9	429.3	377.6
IWP	29.3	21.1	82.8	110.0	625.5	479.3	1080.7	829.8	819.9	556.8	9.3	25.2	164.9	517.4	353.5
SE ±	14.6	17.2	32.5	91.2	106.2	87.4	274.5	120.6	193.0	129.4	5.8	18.6	96.0	194.0	180.0
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean	34.3	35.2	102.3	117.6	560.4	551.6	911.9	784.8	765.9	595.5	10.8	33.3	207.4	476.5	404.4
S x M															
SN	39.7	43.9	107.6	149.1	572.9	535.5	999.4	791.4	839.0	606.6	10.2	34.9	202.5	432.5	391.5
SW	29.8	40.3	99.5	113.5	566.1	511.8	1002.4	753.6	773.6	571.9	15.4	43.5	211.9	647.0	479.8
IN	36.0	34.7	110.5	113.7	542.6	619.8	726.8	794.9	671.5	614.3	8.0	26.9	211.1	352.5	380.7
IW	31.8	22.1	91.7	94.3	559.9	539.3	919.3	799.4	779.7	589.3	9.7	27.8	203.9	473.3	365.5
S x P															
SE	32.2	37.2	102.2	136.8	541.1	457.0	931.7	753.5	794.4	640.5	10.6	41.6	208.2	534.4	437.9
SP	37.3	47.0	104.9	125.8	597.9	590.2	1070.1	791.4	818.2	538.0	15.0	36.8	206.2	545.6	431.6
IE	32.5	35.5	104.1	118.8	508.9	615.2	745.4	754.3	707.4	625.5	9.3	31.1	241.6	438.0	384.5
IP	35.4	21.3	98.1	89.2	593.6	543.9	900.7	840.0	743.8	578.1	8.4	35.0	173.4	387.8	361.8
M x P															
NE	33.7	43.6	102.8	163.8	515.2	524.1	876.8	752.3	777.0	632.9	8.5	36.4	221.4	433.8	369.9
NP	42.0	35.0	115.3	99.0	600.3	631.1	849.3	834.0	733.6	587.9	9.7	25.4	192.3	351.2	402.3
WE	30.9	29.1	103.6	91.8	534.8	548.1	800.3	755.5	724.8	633.1	11.4	36.3	228.5	538.6	454.3
WP	30.7	34.6	87.7	116.0	591.2	503.0	1121.4	797.5	828.4	528.1	13.7	35.0	187.3	582.2	391.0
SE ±	10.4	12.2	23.2	65.0	75.8	62.5	196.2	86.2	137.8	92.2	4.1	13.3	68.6	138.4	128.5
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
System															
S	34.7	42.1	103.5	131.3	569.5	523.6	1000.9	772.5	807.0	589.2	12.8	39.2	207.2	540.0	435.6
I	33.9	28.4	101.1	104.0	551.2	579.5	823.0	797.2	725.6	601.8	8.9	27.4	207.5	412.9	373.1
Method															
N	37.8	39.3	109.0	131.4	557.8	577.6	863.1	793.1	755.3	610.4	9.1	30.9	206.8	392.5	386.1
W	30.8	31.2	95.6	103.9	563.0	525.5	960.8	776.5	776.6	580.6	12.6	35.7	207.9	560.4	422.7
Pattern															
E	32.3	36.4	103.2	127.8	525.0	536.1	838.5	753.9	750.9	633.0	10.0	36.4	224.9	486.2	412.1
P	36.3	34.1	101.5	107.5	595.7	567.0	985.4	815.7	781.0	558.0	11.7	30.2	189.8	466.7	396.7
SE ±	7.3	8.6	16.2	45.6	53.1	43.7	137.2	60.3	96.5	64.7	2.9	9.3	48.0	97.0	9.0
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Planting system indicated that the sole crop superceded sunflower sown associated with groundnut during the *kharif* season, while, this trend was not persistent in either of the summer seasons. The uptake of potassium between the two systems, however, could not be discriminated as significantly different at any stage in the three seasons.

There were no large differences in the quantum of potassium removed by the stem irrespective of the planting method following narrow or wider row spaces. There was a general tendency of greater removal in the wider row treatments during *kharif*, 1983 while the reverse was true during summer, 1984. But, none of the comparisons were significant at any stage.

Statistical scrutiny of the variance also indicated that the pattern of potassium uptake did not respond significantly to the row arrangements in an equidistant or paired row pattern. Response to the interactions both of lower and higher order were not significant.

c. **Capitulum** : The uptake of potassium increased steadily from flower bud formation till seed filling stage in the summer seasons and upto harvest in *kharif* (Table 20). Potassium removed by the buds during summer 1983 and 1984 averaged 11.3 and 31.0 mg $plant^{-1}$ and in *kharif* the uptake was 12.0 mg $plant^{-1}$. The uptake peaked at flowering with 830.2 and 816.7 mg $plant^{-1}$ in the summer seasons and at maturity with 332.0 mg $plant^{-1}$ in *kharif*.

Table 20. Potassium uptake (mg per plant) by the capitulum of sunflower as influenced by different treatments

Treatment	Summer 45 DAS 1983	Summer 45 DAS 1984	Summer 60 DAS 1983	Summer 60 DAS 1984	Summer 75 DAS 1983	Summer 75 DAS 1984	Summer 90 DAS 1983	Summer 90 DAS 1984	Kharif 1983 45 DAS	Kharif 1983 60 DAS	Kharif 1983 75 DAS	Kharif 1983 90 DAS
SNE	5.7	47.2	300.4	454.1	821.3	886.4	724.8	971.5	12.8	44.0	326.4	331.0
SNP	12.3	42.1	332.8	571.2	972.9	869.5	870.5	799.3	9.0	40.0	315.0	331.8
SWE	19.6	29.8	333.7	476.8	819.0	798.3	803.0	712.8	13.5	42.2	429.4	389.5
SWP	14.8	36.5	379.4	415.8	775.8	846.0	970.4	808.4	12.1	58.3	467.0	389.2
INE	10.3	47.7	327.8	516.2	876.9	694.4	842.1	728.2	13.9	41.0	288.4	313.9
INP	9.3	15.2	327.5	413.5	764.0	806.0	731.1	784.4	10.8	52.6	235.2	327.6
IWE	10.2	16.8	332.9	490.3	782.5	874.5	733.5	890.2	9.1	43.1	257.8	277.6
IWP	9.4	12.9	373.8	446.6	829.4	758.2	829.5	817.8	14.9	51.5	253.8	295.3
SE ±	5.2	10.4	16.0	185.0	28.2	202.0	31.4	240.0	4.2	22.0	175.0	152.0
CD 5%	NS	22.3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean	11.3	31.0	338.5	473.1	830.2	816.7	813.1	814.1	12.0	46.6	321.6	332.0
S x M												
SN	8.9	44.6	316.6	512.6	897.1	877.9	797.6	885.4	10.9	42.0	320.7	331.4
SW	17.2	33.1	356.6	446.3	797.4	822.1	886.7	760.6	12.8	50.2	448.2	389.3
IN	9.8	31.4	327.6	464.8	820.4	750.2	786.6	756.3	12.3	46.8	261.8	320.7
IW	9.8	14.8	353.3	468.4	805.9	816.3	781.5	854.0	12.0	47.3	255.8	286.4
S x P												
SE	12.6	38.5	317.0	465.4	820.1	842.3	763.9	842.1	13.1	43.1	377.9	360.2
SP	13.4	39.3	356.1	493.5	874.3	857.7	920.4	803.8	10.5	49.1	391.0	360.5
IE	10.2	32.2	330.3	503.2	829.7	784.4	787.8	809.2	11.5	42.0	273.1	295.7
IP	9.3	14.0	350.6	430.0	796.7	782.1	780.3	801.1	12.8	54.9	244.5	311.4
M x P												
NE	8.0	47.4	314.1	485.1	849.1	790.4	763.9	849.8	13.3	42.5	307.4	322.4
NP	10.7	28.6	330.1	492.3	868.4	837.7	800.8	791.8	9.9	46.3	275.1	329.7
WE	14.9	23.3	333.3	483.5	800.7	836.4	768.2	801.5	11.3	42.6	343.6	333.5
WP	12.1	24.7	376.6	431.2	802.6	802.1	899.9	813.1	13.5	54.9	360.4	342.2
SE ±	3.7	7.4	11.4	132.1	20.0	144.3	22.4	171.4	3.0	15.7	125.0	108.0
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
System												
S	13.0	38.9*	336.5	479.4	847.2	850.0	842.2	823.0	11.8	46.1	384.4	360.4
I	9.8	23.1	340.5	466.6	813.2	783.3	784.0	805.1	12.2	47.0	256.8	303.6
Method												
N	9.3	38.0	322.1	488.7	847.2	814.1	842.2	820.8	11.6	44.4	291.2	326.0
W	13.5	24.0	354.9	457.4	813.2	819.2	784.0	807.3	12.4	48.8	352.0	337.9
Pattern												
E	11.4	35.4	323.7	484.3	824.9	813.4	775.8	825.7	12.3	42.5	325.5	328.0
P	11.4	26.7	353.4	461.8	835.5	819.9	850.4	802.5	11.7	50.6	317.7	335.9
SE ±	2.6	5.2	8.0	92.5	14.1	101.0	15.7	120.0	2.1	11.0	87.5	76.0
CD 5%	NS	11.1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 22. Number of branches per plant in groundnut as influenced by different treatments

Treatment	Summer 30 DAS 1983	30 1984	45 1983	45 1984	60 1983	60 1984	75 1983	75 1984	90 1983	90 1984	105 1983	105 1984	120 1983	Kharif 1983 30	45	60	75	90	105
SNE	3.05	3.18	4.16	4.20	5.98	4.73	6.88	5.33	5.80	5.27	5.66	4.77	5.33	3.63	4.40	4.70	4.47	4.67	4.33
SNP	3.36	3.17	3.73	4.07	4.86	4.67	4.40	5.00	6.26	4.80	5.40	4.57	4.60	3.53	4.20	4.40	5.13	4.40	4.20
SWE	2.97	2.35	3.73	4.13	6.00	4.63	7.06	5.00	5.06	4.80	4.73	4.78	4.86	4.00	4.20	4.93	4.87	4.53	5.53
SWP	3.10	3.18	3.86	3.87	5.70	4.47	4.86	4.47	5.13	5.00	6.06	4.22	5.46	3.63	3.93	4.33	4.30	4.27	4.40
INE	2.81	3.25	2.66	4.17	3.93	4.07	3.73	4.27	3.53	4.47	4.06	3.66	3.93	3.40	4.00	4.17	4.33	4.13	4.33
INP	3.02	3.22	3.30	4.13	4.06	4.20	3.44	4.00	3.80	4.68	4.13	3.83	4.06	3.77	3.73	4.13	4.07	4.23	4.53
IWE	3.21	3.03	2.93	3.98	4.13	4.20	3.89	4.80	3.83	5.58	3.86	4.06	5.06	3.50	3.93	4.47	4.40	4.47	4.73
IWP	2.86	3.47	3.22	4.22	4.04	4.13	3.88	4.48	3.50	4.73	4.40	4.03	3.46	3.63	4.13	3.73	3.47	3.83	4.13
SE ±	0.32	0.51	0.36	0.39	0.56	0.39	0.50	0.53	0.49	0.43	4.15	0.32	0.65	0.25	0.31	0.52	0.20	0.36	0.52
C.D. 5%	0.69	NS	0.78	NS	1.19	NS	1.06	NS	1.06	NS	NS	0.69	1.40	NS	NS	NS	0.43	NS	NS
Mean	3.04	3.10	3.45	4.09	4.84	4.38	4.76	5.03	4.61	5.04	4.78	4.24	4.59	3.63	4.06	4.35	4.38	4.31	4.52
S x M																			
SN	3.20	3.17	3.95	4.13	5.42	4.70	5.64	5.17	6.03*	5.03	5.53	4.67	4.97	3.58	4.30	4.55	4.80	4.53	4.27
SW	3.03	2.77	3.80	4.00	5.85	4.55	5.97	4.73	5.09	4.90	5.39	4.50	5.16	3.82	4.07	4.63	4.58	4.40	4.97
IN	2.91	3.24	2.98	4.15	4.00	4.13	3.59	4.13	3.67	4.57	4.10	3.74	4.00	3.58	3.87	4.15	4.20	4.18	4.43
IW	3.03	3.25	3.07	4.10	4.09	4.21	3.90	4.64	3.67	5.25	4.13	4.04	4.27	3.57	4.03	4.10	3.93	4.15	4.43
S x P																			
SE	3.01	2.77	3.95	4.17	5.99	4.68	6.97**	5.17	5.43	5.03	5.19	4.77	5.10	3.82	4.30	4.82	4.67**	4.60	4.93
SP	3.23	3.17	3.80	3.97	5.28	4.57	4.63	4.73	5.69	4.90	5.73	4.39	5.03	3.58	4.70	4.37	4.72	4.33	4.30
IE	3.01	3.14	2.80	4.07	4.03	4.17	3.81	4.53	3.68	5.02	3.96	3.86	4.50	3.45	3.97	4.32	4.37	4.30	4.53
IP	2.94	3.34	3.26	4.17	4.05	4.17	3.68	4.24	3.65	4.70	4.27	3.93	3.77	3.70	3.93	3.93	3.77	4.03	4.33
M x P																			
NE	2.93	3.22	3.42	4.18	4.96	4.40	5.31	4.80	4.67	4.87	4.87	4.21	4.63	3.52	4.20	4.43	4.40**	4.40	4.33
NP	3.19	3.19	3.52	4.10	4.47	4.43	3.92	4.50	5.03	4.74	4.77	4.20	4.33	3.65	3.97	4.27	4.60	4.32	4.37
WE	3.09	2.69	3.33	4.05	5.07	4.46	5.48	4.90	4.44	5.19	5.77	4.42	4.97	3.75	4.07	4.70	4.63	4.50	5.13
WP	2.98	3.32	3.54	4.04	4.87	4.30	4.39	4.74	4.31	4.86	5.23	4.12	4.46	3.63	4.03	4.03	3.88	4.05	4.27
SE ±	0.21	0.36	0.26	0.28	0.39	0.27	0.35	0.37	0.35	0.30	0.81	0.23	0.46	0.17	0.22	0.36	0.14	0.26	0.37
CD 5%	NS	NS	NS	NS	NS	NS	0.72	NS	0.75	NS	NS	NS	NS	NS	NS	NS	0.30	NS	NS
System																			
S	3.12	2.97	3.87**	4.07	5.64**	4.62*	5.80**	4.95**	5.56**	4.97	5.46*	4.58**	5.06*	3.70	4.18	4.59	4.69**	4.47	4.62
I	2.97	3.24	3.03	4.12	4.04	4.17	3.74	4.38	3.67	4.86	4.11	3.89	4.13	3.57	3.95	4.12	4.07	4.17	4.43
Method																			
N	3.06	3.21	3.47	4.14	4.71	4.42	4.61	4.65	4.85	4.80	4.82	4.21	4.48	3.58	4.08	4.35	4.50	4.36	4.35
W	3.03	3.01	3.44	4.05	4.97	4.38	4.93	4.68	4.38	5.03	4.76	4.27	4.71	3.69	4.05	4.37	4.26	4.27	4.70
Pattern																			
E	3.01	2.95	3.37	4.12	5.01	4.43	5.39**	4.85	4.56	5.03	4.58	4.32	4.80	3.63	4.13	4.57	4.52*	4.45	4.73
P	3.08	3.26	3.53	4.07	4.67	4.37	4.15	4.48	4.67	4.80	5.00	4.16	4.39	3.64	4.00	4.15	4.24	4.18	4.32
SE ±	0.16	0.25	0.18	0.20	0.28	0.19	0.25	0.26	0.25	0.21	0.57	0.16	0.32	0.12	0.15	0.26	0.10	0.18	0.26
CD 5%	NS	NS	0.39	NS	0.60	0.42	0.53	0.56	0.52	NS	1.23	0.34	0.70	NS	NS	NS	0.21	NS	NS

Method of planting did not influence the number of branches per plant in any season. Groundnut sown in the narrow/ wider row treatments performed equally well with no definite trend of variation to demarcate the significance of either row width treatments.

Planting pattern indicated that the equidistant row arrangement generally favoured more branching in the <u>kharif</u> season though the significant effect was observed only at 75 days. In the summer seasons, branching however, did not reveal a particular trend in response to the row arrangement treatments, though the equidistant row pattern registered significantly more number of branches per plant at 75 days during summer 1983.

The interactions were not significant at most of the sampling periods. Planting system interacted with planting pattern at 75 days and with planting method at 90 days during summer, 1983. In <u>kharif</u>, the interaction was between planting system and pattern and also between planting method and pattern at 75 days.

4.2.1.3 Number of leaves per plant

The mean number of leaves per plant of groundnut increased progressively from 14.08 and 12.32 recorded at 30 days during summer 1983 and 1984 to a maximum of 81.63 and 58.80 at 105 and 90 days during the corresponding seasons. In <u>kharif</u> leaves increased from a mean number of 17.56 at 30 days to a maximum of 49.23 at 75 days. This was followed by a precipituous decline retaining 13.61, 47.57 and 12.17 leaves plant^{-1} at harvest during the summer seasons and *kharif* as well (Table 23).

Planting system exerted a tremendous influence while the magnitude of variation in leaf number due to the method or pattern of planting was not strikingly different. Sunflower associated with groundnut had a drastic effect in reducing the number of leaves throughout the growth stages. Sole crop of groundnut consistently had more number of leaves than in intercrop system and these differences were significantly ameliorated at every sampling except at 30 days during summer 1983 and at 120 days during summer, 1984. In *kharif* a reverse trend was observed at harvest in that the leaf retention by the intercropped groundnut was significantly more than the sole crop.

Leaf production did not follow a regular trend of variation due to the method or pattern of planting. During summer, 1983 wider rows had significantly greater number of leaves than the narrow rows at 60 days while the reverse was true at 90 days sampling. Leaf number did not differ significantly at all other stages.

The effect of planting pattern was not well marked and had a considerably irregular trend except for a significant effect of increased leaf number in the equidistant row treatment over the paired pattern at 60 days during *kharif*, 1983.

None of the interactions were significant in the summer seasons except the interaction between planting system

Table 23. Number of leaves per plant of groundnut as influenced by different treatments

Treatment	Summer 30 DAS 1983	Summer 30 DAS 1984	Summer 45 DAS 1983	Summer 45 DAS 1984	Summer 60 DAS 1983	Summer 60 DAS 1984	Summer 75 DAS 1983	Summer 75 DAS 1984	Summer 90 DAS 1983	Summer 90 DAS 1984	Summer 105 DAS 1983	Summer 105 DAS 1984	Summer 120 DAS 1983	Kharif 1983 30 DAS	Kharif 1983 45 DAS	Kharif 1983 60 DAS	Kharif 1983 75 DAS	Kharif 1983 90 DAS	Kharif 1983 105 DAS
SNE	15.55	14.25	28.73	35.00	54.73	57.00	82.05	83.07	81.26	83.13	80.13	56.11	15.55	19.54	40.13	54.25	44.60	50.27	7.85
SNP	14.88	13.05	29.20	36.67	47.40	52.67	53.91	65.53	102.90	61.93	114.80	60.92	14.88	16.88	36.87	48.13	57.93	63.20	9.47
SWE	12.73	11.60	31.80	38.80	60.48	52.63	57.63	66.67	72.26	64.80	91.26	50.55	12.77	19.44	43.67	56.80	65.93	44.00	4.73
SWP	13.55	13.55	23.15	36.00	55.00	53.33	53.00	49.80	59.60	56.20	88.33	51.09	13.55	18.66	35.27	38.47	57.42	42.07	7.80
INE	14.63	11.75	23.37	39.08	28.55	33.27	36.46	48.60	35.33	45.13	47.40	41.02	14.16	15.89	39.87	43.77	46.00	36.20	5.73
INP	11.55	10.26	22.58	35.04	29.38	37.80	38.98	37.87	47.06	42.92	55.13	36.87	11.55	16.66	33.53	39.47	36.73	32.02	16.53
IWE	13.22	9.83	23.80	35.22	37.33	42.52	33.18	49.67	32.26	66.40	67.40	40.95	13.22	16.33	34.13	42.53	53.52	45.00	15.93
IWP	16.55	14.25	22.15	30.84	37.65	41.33	37.43	46.96	42.26	49.87	68.60	43.08	13.22	17.11	38.08	38.03	37.68	40.52	29.35
SE±	3.23	2.43	3.75	5.08	5.81	7.42	11.56	11.20	12.59	7.73	18.27	12.50	3.23	2.37	5.62	7.68	9.23	9.51	3.43
CD5%	NS	NS	NS	NS	12.46	NS	24.80	24.03	27.00	16.59	39.20	NS	6.92	NS	NS	NS	NS	NS	7.35
Mean	14.98	12.32	25.59	35.83	43.81	46.31	49.08	56.02	59.12	58.80	81.63	47.57	13.61	17.56	37.69	45.18	49.23	44.16	12.17
S x M																			
SN	15.22	13.65	28.97	35.83	51.07	54.83	67.98	74.30	92.08	72.53**	97.47	58.51	15.22	18.21	38.50	51.19	51.27	56.73*	8.66
SW	13.16	12.57	27.48	37.40	57.74	52.98	55.32	58.23	65.93	60.50	89.79	50.82	13.16	19.05	38.90	47.63	58.71	43.03	6.27
IN	12.86	11.00	22.97	37.06	28.97	35.53	37.72	43.23	41.20	44.02	51.27	38.94	12.86	16.27	36.70	41.62	41.37	34.11	11.13
IW	14.89	12.04	22.97	33.03	37.49	41.92	35.30	48.27	37.27	58.13	68.00	42.01	14.89	16.72	36.11	40.28	45.60	42.76	12.36
S x P																			
SE	14.16	12.92	30.27	36.90	57.61	54.82	69.84	74.87	76.77	73.96	85.69	53.33	14.16	19.49	41.90	55.52	55.30	47.13	6.29
SP	14.22	13.30	26.18	36.33	51.20	53.00	53.45	57.67	81.25	59.06	101.56	56.00	14.22	17.77	35.50	43.30	54.67	52.63	8.63
IE	13.69	10.79	23.58	37.15	32.94	37.89	34.82	49.41	33.80	55.76	111.57	40.98	13.69	16.11	37.00	43.15	49.76	40.60	10.83
IP	14.05	12.25	22.37	32.94	33.52	39.57	38.20	42.41	44.67	46.39	61.87	39.97	14.05	16.88	35.81	38.75	37.21	36.27	12.66
M x P																			
NE	14.86	13.00	26.05	37.04	41.64	45.13	59.26	65.83	58.30	64.13	63.77	48.56	14.86	17.71	40.00	49.01	45.30	43.23	6.79*
NP	13.22	11.65	25.89	35.85	38.39	45.23	46.44	51.70	74.98	52.42	84.97	48.89	13.22	16.77	35.20	43.80	47.33	47.61	13.00
WE	13.00	10.71	27.80	37.01	48.91	47.57	45.40	58.13	52.27	65.60	79.33	45.75	13.00	17.89	38.90	49.67	59.76	44.50	10.33
WP	15.05	13.90	22.65	33.42	46.33	47.33	45.22	48.37	50.93	53.03	78.46	47.08	15.05	17.89	36.11	38.25	44.55	41.29	8.29
SE±	2.82	1.72	2.65	3.59	4.10	5.25	8.18	7.92	8.90	5.47	12.92	8.84	2.28	1.67	3.98	5.43	6.52	6.72	2.42
CD5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	11.73	NS	NS	NS	NS	NS	NS	NS	14.43	5.20
System																			
S	14.91	13.11	28.22*	36.62	54.40**	53.91**	61.65**	66.27**	79.00**	66.51**	93.63**	54.67*	14.19	18.63	38.70	49.41*	54.99*	49.88*	7.46*
I	13.87	11.52	22.97	35.05	33.23	38.73	36.51	45.75	39.23	51.08	59.63	40.48	13.87	16.49	36.40	40.95	43.48	38.43	11.75
Method																			
N	14.04	12.33	25.97	36.45	40.02*	45.18	52.85	58.77	66.64*	58.27	74.37	48.73	14.03	17.24	37.60	46.40	46.32	45.[illegible]2	9.90
W	14.02	12.31	25.23	35.21	47.62	47.45	45.31	53.25	51.60	59.32	78.90	46.42	14.02	17.89	37.50	43.96	52.15	42.90	9.31
Pattern																			
E	13.93	11.86	26.92	37.02	45.27	46.35	52.33	61.98	55.28	64.86	71.54	47.16	13.93	17.80	39.45	49.34*	52.53	43.87	8.56
P	14.14	12.78	24.27	34.63	42.36	46.28	45.83	50.04	62.96	52.73	81.71	47.99	14.14	17.33	35.65	41.02	45.94	44.45	10.65
SE±	1.61	1.21	1.87	2.54	2.90	3.71	5.78	5.60	6.29	3.87	9.14	6.25	1.61	1.18	2.81	3.84	4.61	4.76	1.71
CD5%	NS	NS	4.02	NS	6.23	7.96	12.40	12.00	13.50	8.30	19.60	13.41	NS	NS	NS	8.24	9.89	10.20	3.68

and method at 90 days during 1984. In *kharif*, barring the interaction between planting system and method at 90 days while planting method and pattern at 105 days the other interactions were not significant.

4.2.1.4 Leaf area per plant (cm^2)

The development and maintenance of active leaf area per plant, the major determinant of phytosynthetic potential are presented in Table 24.

The mean leaf area per plant increased progressively from 87.28 and 274.86 cm^2 during the summer seasons and from 146.33 cm^2 in *kharif* at 30 days to a maximum of 916.41 and 763.35 cm^2 at 90 days in the summer seasons and to 710.52 cm^2 at 75 days in *kharif*.

Leaf area was influenced significantly with planting system. Production and maintenance of leaf area was exceedingly high in the sole crop. Except in the initial sampling (30 days) the leaf area of groundnut intercropped with sunflower was significantly reduced at all the stages in the summer seasons. Similarly in *kharif*, the sole crop performed better than the intercropped groundnut. But, the differences were significant at 45 and 75 days. At harvest, the intercropped groundnut retained marginally greater leaf area than the sole crop.

The difference in leaf area per plant by the planting method was not substantial and did not follow a regular trend. The wider rows exceptionally had a significantly greater leaf area than the narrow rows at 75 days during summer, 1983.

The uptake of potassium by the capitulum in intercrop system was relatively low than the sole crop in most instances. However, the differences were not significant at any stage in the three trials except at 30 days sampling during summer, 1984. In kharif the removal of potassium was marginally better in the wider rows while this trend was not persistent in the summer seasons.

Acquisition of potassium in the capitulum was identical with only numerical differences irrespective of the row arrangement sunflower was planted in an equidistant or paired row pattern in the three seasons.

None of the interactions were significant at any stage in the three seasons except at 30 days during summer 1984 when planting system interacted significantly with planting method and also with planting pattern.

4.2 GROUNDNUT

4.2.1 Morpho-physiological characteristics

4.2.1.1 Plant height (cm)

The mean plant height of groundnut increased from 4.54 and 6.80 cm at 30 days sampling in the summer seasons during 1983 and 1984 and from 7.41 cm in kharif during 1983 to a maximum of 24.61, 21.44 and 22.32 cm at harvest during the corresponding seasons (Table 21). The effect of different treatments on plant height was not remarkable at any stage.

Planting system had no marked influence on the plant height of groundnut. The crop in intercrop system generally

Table 21. Plant height (cm) of groundnut as influenced by different treatments

Treatment	Summer 30 DAS 1983	Summer 30 DAS 1984	Summer 45 DAS 1983	Summer 45 DAS 1984	Summer 60 DAS 1983	Summer 60 DAS 1984	Summer 75 DAS 1983	Summer 75 DAS 1984	Summer 90 DAS 1983	Summer 90 DAS 1984	Summer 105 DAS 1983	Summer 105 DAS 1984	Summer 120 DAS 1983	Kharif 1983 30 DAS	Kharif 1983 45 DAS	Kharif 1983 60 DAS	Kharif 1983 75 DAS	Kharif 1983 90 DAS	Kharif 1983 105 DAS
SNE	4.15	6.18	8.96	10.27	14.52	17.20	20.26	23.40	20.36	25.67	20.53	25.83	21.20	8.61	15.33	20.12	20.73	20.80	20.88
SNP	4.79	6.78	9.36	10.93	13.66	16.13	19.42	18.67	20.30	24.67	21.86	25.52	21.53	7.48	12.93	20.47	21.13	22.27	23.33
SWE	4.88	6.30	9.64	10.07	13.36	14.17	16.00	20.60	18.06	22.83	18.80	23.95	19.86	7.66	15.40	20.73	20.60	22.13	22.07
SWP	4.24	7.42	7.54	10.20	13.02	15.93	14.66	18.20	18.86	22.33	20.60	22.65	20.93	7.33	16.07	19.93	20.40	23.82	23.33
INE	4.41	7.13	7.18	12.33	13.80	17.47	17.86	18.27	17.26	22.47	21.73	22.87	22.50	7.11	14.87	21.12	21.07	21.67	23.20
INP	4.83	7.01	7.95	12.48	15.78	18.67	15.95	24.13	18.33	24.12	21.53	25.37	21.73	6.89	16.67	21.80	21.43	22.73	22.67
IWE	4.86	6.78	7.18	11.16	14.83	18.87	14.33	22.60	16.58	23.95	18.93	24.13	19.66	7.05	13.47	21.00	21.20	21.53	21.60
IWP	4.21	6.83	7.03	13.28	16.56	20.22	17.26	21.00	21.86	22.40	21.80	26.60	24.13	7.22	16.00	21.37	21.30	22.68	22.78
SE±	0.62	0.77	0.94	1.20	3.48	2.97	3.81	2.97	4.18	3.41	4.02	3.24	2.60	1.00	1.58	2.00	1.57	1.66	1.55
CD5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean	4.54	6.80	8.10	11.34	14.44	17.33	16.96	20.86	19.07	23.55	20.57	24.61	21.44	7.41	15.09	20.81	20.98	22.20	22.32
S x M																			
SN	4.47	6.48	9.17	10.60	14.09	16.67	19.84	21.03	20.33	25.17	21.20	25.67	21.36	7.97	14.13	20.29	20.93	21.53	21.71
SW	4.56	6.86	8.59	10.13	13.19	15.05	15.33	19.40	18.47	22.67	19.70	23.30	20.40	7.50	15.73	20.33	20.50	22.97	22.70
IN	4.62	7.07	7.57	12.41	14.79	18.07	16.91	21.20	17.80	23.29	21.63	24.12	22.12	7.00	15.77	21.46	21.25	22.20	22.93
IW	4.54	6.81	7.11	12.22	15.69	19.54	15.80	21.80	19.22	23.17	19.77	25.36	21.90	7.13	14.73	21.18	21.25	22.10	21.94
S x P																			
SE	4.52	6.24	9.30	10.17	13.94	15.68	18.13	22.00	19.21	24.33	19.67	24.89	20.53	8.14	15.37	20.42	20.67	21.46	21.07
SP	4.51	7.10	8.45	10.57	13.34	16.03	17.04	18.43	19.58	23.50	21.23	24.08	21.23	7.33	14.50	20.20	20.77	23.04	23.33
IE	4.64	6.95	7.18	11.74	14.32	18.17	16.10	20.43	16.92	23.20	20.33	23.49	21.08	7.08	14.17	21.06	21.13	21.60	22.40
IP	4.52	6.92	7.49	12.88	16.17	19.44	16.61	22.57	20.10	23.26	21.17	25.98	22.93	7.05	16.33	21.58	21.37	22.70	22.47
M x P																			
NE	4.29	6.65	8.07	11.30	14.16	17.33	19.07	20.83	18.81	24.07	21.13	24.35	21.85	7.86	15.10	20.62	20.90	21.23	21.64
NP	4.80	6.90	8.66	11.71	14.72	17.40	17.69	21.40	19.31	24.39	21.70	25.44	21.63	7.11	14.80	21.13	21.28	22.50	23.00
WE	4.87	6.54	8.41	10.61	14.10	16.52	15.17	21.60	17.32	23.47	18.77	24.04	19.77	7.36	14.43	20.87	20.90	21.83	21.83
WP	4.22	7.12	7.29	11.74	14.79	18.07	15.97	19.60	20.37	22.37	20.70	24.62	22.53	7.27	16.03	20.65	20.85	23.25	22.81
SE ±	0.44	0.55	0.66	0.85	2.46	1.54	2.69	2.10	2.96	2.41	2.84	2.29	1.84	0.71	1.11	1.42	1.11	1.18	1.10
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
System																			
S	4.51	6.67	8.88	10.37**	13.64	15.86*	17.59	20.22	19.39	23.92	20.45	24.48	20.88	7.73	14.93	20.31	20.72	22.25	22.20
I	4.58	6.93	7.34	12.31	15.24	18.80	16.35	21.50	18.50	23.23	20.70	24.74	22.00	7.07	15.25	21.32	21.25	22.15	22.44
Method																			
N	4.54	6.77	8.37	11.50	14.44	17.37	18.38	21.12	19.57	24.23	21.42	24.90	21.74	7.48	14.95	20.87	21.09	21.86	22.32
W	4.55	6.83	7.85	11.18	14.44	17.30	15.57	20.60	18.85	22.92	19.73	24.33	21.15	7.32	15.23	20.76	20.87	22.54	22.32
Pattern																			
E	4.58	6.59	8.24	10.96	14.13	16.92	17.12	21.22	19.06	23.77	19.95	24.18	20.31	7.61	14.77	20.74	20.90	21.53	21.74
P	4.51	7.00	7.97	11.72	14.75	17.74	16.83	20.50	20.84	23.38	21.20	25.03	20.80	7.19	15.42	20.89	21.07	22.87	22.90
SE ±	0.31	0.39	0.47	0.60	1.74	1.09	1.90	1.49	2.09	1.70	2.01	1.62	1.30	0.50	0.79	1.00	0.79	0.83	0.77
CD 5%	NS	NS	NS	1.29	NS	2.34	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

tended to grow taller than the monoculture though this effect was not significant except at 45 and 60 days sampling during summer, 1984.

Planting method or planting pattern seemed to have no influence on the plant height of groundnut althrough the crop growth period. Plants sown in narrow rows or wide apart and those sown in equidistant or paired row pattern attained similar heights that were all statistically on par at each sampling.

The interactions both of the first and second order were not significant at any stage in the three seasons.

4.2.1.2 Number of branches per plant

The data presented in Table 22, revealed that most of the branches were produced (3.04, 3.10 and 3.63 $plant^{-1}$) by 30 days sampling though branching continued steadily upto 75 days (4.76, 5.03 and 4.38 $plant^{-1}$) and ceased practically thereafter.

Planting system manifested a pronounced influence on the branching of groundnut. Sunflower as a companion had an adverse effect on the number of branches borne per plant. Branching was severely affected resulting in a significant reduction, except at 30 days during the summer seasons and at 45 and 90 days during summer, 1984. In *kharif*, similar reduction in number of branches per plant were recorded in the intercrop system althrough the samplings. However, this reduction was not significant at any stage except at 75 days.

Table 24. Leaf area per plant (cm^2) of groundnut as influenced by different treatments

Treat-ment	Summer: 30 DAS 1983	30 1984	45 1983	45 1984	60 1983	60 1984	75 1983	75 1984	90 1983	90 1984	105 1983	105 1984	120 1983	Kharif 1983: 30	45	60	75	90	105
SNE	94.51	216.94	256.44	291.39	695.35	731.32	1018.24	1092.91	1093.28	1171.48	1020.64	721.03	225.46	169.19	360.57	491.29	696.43	442.52	80.10
SNP	113.30	126.52	271.35	296.97	600.56	610.11	835.31	968.21	1472.96	786.41	1504.19	574.31	198.64	133.12	347.34	374.85	882.35	482.16	134.67
SWE	94.51	122.45	270.87	311.27	698.39	770.45	1175.04	975.68	1293.76	881.13	1297.09	889.89	192.50	173.76	351.19	336.20	768.11	356.68	112.54
SWP	67.17	128.54	233.60	310.79	706.50	590.07	846.13	806.41	912.21	676.13	770.96	490.39	200.10	160.55	329.07	327.13	837.55	322.06	91.43
INE	77.24	106.20	226.15	238.17	190.17	480.79	488.85	573.23	626.98	645.35	377.65	405.46	169.47	134.65	349.74	300.88	625.12	261.32	62.59
INP	80.28	168.17	225.66	246.83	236.94	365.79	510.13	494.08	646.40	573.28	404.42	358.10	148.85	122.96	293.96	290.39	606.83	225.28	198.51
IWE	83.85	122.61	213.64	265.34	247.44	465.04	544.10	588.16	588.90	705.07	325.66	380.75	172.37	133.12	291.80	303.74	690.45	468.78	144.97
IWP	87.40	132.61	222.05	238.17	287.52	400.14	587.04	575.47	696.80	669.55	473.92	440.98	154.92	143.28	308.01	331.90	577.33	368.39	95.04
SE±	19.94	57.59	16.66	24.96	102.25	119.79	52.39	72.68	154.07	138.12	211.75	119.45	19.85	25.48	22.60	86.85	102.67	120.37	55.01
CD5%	NS	NS	35.74	53.54	219.32	256.96	112.39	155.90	330.49	296.29	454.20	256.23	42.76	NS	48.47	NS	NS	NS	NS
Mean	87.28	274.86	239.97	274.86	457.88	551.71	750.60	759.27	916.41	763.35	771.82	532.61	182.79	146.33	328.96	344.54	710.52	365.90	114.98
S x M																			
SN	103.91	171.73	263.90	294.20	648.04	670.71	926.77	1030.56*	1283.12	978.95	1282.42	647.67	212.05	151.15	353.96	433.07	789.39	462.34*	107.38
SW	80.84	125.50	252.24	311.03	702.45	680.26	1010.59	891.05	1102.99	778.69	1034.03	690.14	196.30	167.15	340.13	331.66	802.83	339.37	101.98
IN	78.76	137.18	225.91	242.50	243.56	423.29	499.49	533.65	636.69	609.32	391.04	381.78	159.16	128.80	321.85	295.63	615.97	243.30	130.55
IW	85.62	127.61	217.85	251.76	267.48	432.59	565.57	581.81	642.85	687.31	399.80	410.86	163.64	138.20	299.85	317.82	633.89	418.58	120.00
S x P																			
SE	94.51	169.69	263.66	301.29	696.96	750.88	1096.64**	1034.29*	1193.52	1026.30	1158.87	805.46*	208.98	171.47	355.88	413.74	732.27	399.60	96.32
SP	90.24	127.53	252.48	303.94	653.53	600.09	840.72	887.31	1192.59	731.27	1157.58	532.25	199.37	146.84	338.20	350.99	859.95	402.11	113.05
IE	80.54	114.40	219.90	251.76	248.81	472.91	516.48	580.69	607.95	675.21	351.66	393.10	170.80	133.88	320.77	302.31	657.79	365.05	103.78
IP	83.84	150.39	223.86	242.50	262.23	382.96	548.59	534.77	671.60	621.41	439.18	399.54	151.88	133.12	300.93	311.14	592.08	296.84	146.77
M x P																			
NE	85.88	161.57	241.30	264.74	472.85	606.05	753.55	833.07	860.13	908.41	699.15	563.24	197.46	151.92	355.16	396.09	660.77	351.92	71.34*
NP	96.79	147.34	248.51	271.95	418.75	487.95	672.72	731.14	1059.68	679.84	674.31	466.20	173.74	128.04	320.65	332.62	744.59	353.72	166.59
WE	89.18	122.53	242.26	288.31	472.92	617.74	859.57	781.92	941.33	793.10	811.38	635.32	182.43	153.44	321.49	319.97	729.28	412.73	128.75
WP	77.29	130.58	227.83	274.48	497.01	495.10	716.59	690.94	804.51	672.84	622.44	465.68	177.51	151.91	318.49	329.52	707.44	345.23	93.23
SE±	14.10	40.72	11.78	17.65	72.30	84.71	37.05	51.39	108.95	97.67	149.73	84.45	14.07	17.98	15.98	61.41	72.60	85.11	38.90
CD5%	NS	NS	NS	NS	NS	NS	79.47	110.24	NS	NS	NS	181.18	NS	NS	NS	NS	NS	182.56	83.44
System																			
S	92.38	148.61	258.07**	302.61**	675.25**	675.49**	968.68**	960.80**	1193.05**	878.82**	1158.22**	668.90**	204.17**	159.15	347.04**	382.37	796.11**	400.86	104.68
I	82.19	132.40	221.88	247.13	255.52	427.94	532.53	557.73	639.77	648.31	395.42	396.32	161.40	133.50	310.85	306.73	624.93	330.94	125.28
Method																			
N	91.34	154.46	244.90	268.35	445.80	547.00	713.13*	782.11	959.91	794.13	836.73	514.72	185.60	139.98	337.90	364.35	702.68	352.82	118.97
W	83.23	126.55	235.04	281.39	464.96	556.42	788.09	736.43	872.92	733.00	716.91	550.50	179.97	152.68	319.99	324.74	718.36	378.98	110.99
Pattern																			
E	87.53	276.52	241.78	276.52	472.88	611.90	806.56**	557.49	900.73	850.75	755.26	599.28*	189.95	152.68	338.32	358.03	695.03	382.32	100.05
P	87.04	273.22	238.17	273.22	457.88	491.53	694.65	711.04	932.09	676.34	798.38	465.94	175.62	139.98	319.57	331.07	726.01	349.47	129.91
SE±	9.97	28.79	8.33	12.48	51.12	59.90	26.19	36.34	77.04	69.06	105.87	59.73	9.92	12.71	11.30	43.42	51.33	60.18	27.51
CD5%	NS	NS	17.87	26.77	109.66	128.48	56.19	77.95	165.25	148.14	227.10	128.12	21.28	NS	24.23	NS	110.11	NS	NS

The equidistant row arrangement generally had better canopy coverage upto 60 days, while, this trend did not persist in the later stages. There were however, no significant differences at any stage except at 75 days during summer, 1983 and 105 days during summer, 1984.

Planting system showed a significant interaction with planting method at 75 days during summer 1984 and at 90 days in kharif. Interaction between planting system and pattern presented a significant response at 75 days during the summer seasons and only at 105 days during summer, 1984 and kharif, 1983. Interactions at all other stages were not significant.

4.2.1.5 Phytomass accumulation (g plant^{-1})

Findings related to the accumulation of phytomass in leaves, stem and pods at different stages of crop growth are presented separately.

4.2.1.5.1 Leaves:

The phytomass of leaves followed an increasing-diminishing trend with crop age in consonance with the rate of leaf appearance (Table 25). Leaf phytomass increased from 0.38 and 0.73g plant^{-1} at 30 days to a maximum of 6.24 and 5.12 g plant^{-1} at 105 and 90 days during summer, 1983 and summer, 1984 respectively. The leaf weight then decreased to 1.60 and 3.62 g plant^{-1} at harvest. In kharif it increased from 0.76 g at 30 days to a maximum of 3.37 g plant^{-1} at 75 days and declined (0.92 g plant^{-1}) at harvest.

Planting system exerted a significant influence on the dry matter production of leaves per plant. Reduction in weight was considerably high in groundnut intercropped with sunflower. The differences were significant at every sampling in the summer seasons except at 30 and 120 days during 1983 and at 30 days alone during, 1984. This trend was also apparent in the kharif season. But, the differences were significant at 45 and 75 days.

Planting method did not show a marked variation in the phytomass accumulation in any season. The leaf phytomass in narrow and wider row treatments was on par at every stage except at 75 days during summer, 1983.

Planting pattern indicated that the equidistant row spacing had an edge over the paired rows at every stage in the summer seasons. This difference was statistically significant at 75 days during summer, 1983 and at 75, 90 and 105 days during summer, 1984. The trend in kharif was broadly similar but the differences were not significant at any stage.

The first order interactions between system and method were significant at 75 days during summer, 1984 and at 90 days during kharif, 1983. Planting system and pattern interacted significantly at 75 and 105 days during summer, 1983 and 1984 respectively. While, the interaction between planting method and pattern was significant at 90 and 105 days during summer and kharif, 1983 respectively. The second order interactions were not significant at any stage.

Table 25. Leaf phytomass of groundnut (g per plant) as influenced by different treatments

Treat-ment	Days after sowing																			
	30		45		60		75		90		105		120	30	45	60	75	90	105
	Summer													Kharif						
	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984	1983	1983						
SNE	0.54	1.22	1.43	1.70	4.55	4.81	6.12	6.78	6.79	7.27	9.62	4.85	1.80	0.91	2.66	3.13	3.25	3.05	0.69
SNP	0.42	0.63	1.22	1.78	3.89	3.96	4.49	5.67	6.02	5.27	7.50	3.90	1.72	0.68	2.48	2.32	4.91	3.30	1.05
SWE	0.42	0.60	1.42	1.98	4.58	5.08	7.52	5.74	8.58	5.88	8.67	5.94	1.69	0.94	2.53	2.05	3.89	2.49	0.91
SWP	0.33	0.64	0.91	1.97	4.63	3.82	4.58	4.23	5.17	4.56	8.44	3.35	1.77	0.86	2.23	1.98	4.51	2.27	0.77
INE	0.33	0.50	0.80	0.97	1.35	3.06	1.58	2.14	2.80	4.36	3.50	2.80	1.58	0.69	2.51	1.80	2.61	1.87	0.59
INP	0.31	0.90	0.79	1.08	1.03	2.25	1.39	1.44	2.63	3.89	3.10	2.50	1.37	0.61	1.74	1.73	2.45	1.64	1.47
IWE	0.37	0.67	0.74	1.34	1.71	2.95	2.27	2.28	3.25	4.75	5.17	2.65	1.50	0.68	1.71	1.82	3.19	3.22	1.12
IWP	0.35	0.67	0.83	0.97	1.43	2.50	1.89	2.17	2.29	4.52	3.93	3.04	1.40	0.74	1.93	2.02	2.18	2.57	0.80
SE±	0.121	0.37	0.24	0.35	0.70	0.84	0.53	0.65	1.37	0.89	1.58	0.77	0.52	0.17	0.31	0.61	0.92	0.77	0.36
CD5%	NS	NS	0.51	0.74	1.50	1.79	1.14	1.39	2.95	1.92	3.39	1.66	NS	NS	0.67	NS	NS	NS	NS
Mean	0.38	0.73	1.01	1.47	2.90	3.55	3.73	3.80	4.69	5.12	6.24	3.62	1.60	0.76	2.22	2.11	3.37	2.55	0.92
S x M																			
SN	0.48	0.93	1.32	1.74	4.22	4.38	5.30	6.23*	6.40	6.52	8.56	4.37	1.76	0.79	2.57	2.72	4.08	3.17*	0.88
SW	0.38	0.63	1.16	1.98	4.60	4.45	6.05	4.98	6.88	5.22	8.57	4.65	1.73	0.90	2.38	2.01	4.20	2.38	0.84
IN	0.32	0.70	0.80	1.03	1.19	2.65	1.49	1.79	2.72	4.13	3.33	2.65	1.47	0.65	2.13	1.76	2.53	1.76	1.03
IW	0.36	0.67	0.78	1.15	1.57	2.72	2.00	2.22	2.77	4.63	4.55	2.84	1.45	0.71	1.82	1.92	2.69	2.89	0.96
S x P																			
SE	0.48	0.92	1.42	1.84	4.57	4.94	6.82*	6.26	7.68	6.83	9.15	5.40*	1.74	0.93	2.60	2.59	3.57	2.78	0.80
SP	0.38	0.64	1.06	1.88	4.26	3.89	4.53	4.95	5.54	4.92	7.97	3.63	1.74	0.77	2.35	2.15	4.71	2.78	0.91
IE	0.35	0.59	0.77	1.15	1.53	3.00	1.82	2.21	3.02	4.55	4.37	2.73	1.54	0.68	2.11	1.81	2.90	2.54	0.85
IP	0.33	0.79	0.81	1.03	1.23	2.37	1.67	1.80	2.46	4.20	3.52	2.77	1.38	0.68	1.84	1.87	2.31	2.10	1.13
M x P																			
NE	0.44	0.86	1.11	1.33	2.95	3.93	3.85	4.47	4.97*	6.06	6.59	3.83	1.69	0.80	2.59	2.46	2.93	2.46	0.64*
NP	0.37	0.77	1.00	1.43	2.46	3.10	2.94	3.56	6.32	4.58	5.30	3.20	1.54	0.64	2.11	2.02	3.68	2.47	1.26
WE	0.40	0.64	1.08	1.66	3.14	4.01	4.79	4.01	5.92	5.32	6.92	4.29	1.59	0.81	2.12	1.93	3.54	2.85	1.01
WP	0.34	0.66	0.87	1.47	3.03	3.16	3.26	3.20	3.73	4.54	6.19	3.20	1.58	0.80	2.08	2.00	3.34	2.42	0.78
SE±	0.08	0.26	0.17	0.24	0.49	0.59	0.38	0.46	0.97	0.63	1.12	0.55	0.37	0.12	0.22	0.43	0.65	0.55	0.25
CD5%	NS	NS	NS	NS	NS	NS	0.80	0.98	2.08	NS	NS	1.17	NS	NS	NS	NS	NS	1.17	0.54
System																			
S	0.43	0.78	1.24*	1.86*	4.41**	4.42**	5.68**	5.61**	6.64**	5.87*	8.56**	4.51**	1.74	0.85	2.48**	2.37	4.14**	2.78	0.86
I	0.34	0.69	0.79	1.09	1.38	2.69	1.75	2.00	2.74	4.38	3.94	2.75	1.46	0.68	1.97	1.84	2.61	2.32	0.99
Method																			
N	0.40	0.82	1.06	1.38	2.71	3.52	3.40*	4.01	4.56	5.32	5.94	3.51	1.62	0.72	2.35	2.24	3.30	2.47	0.95
W	0.37	0.65	0.97	1.57	3.09	3.58	4.03	3.60	4.82	4.93	6.55	3.75	1.59	0.80	2.10	1.97	3.44	2.63	0.90
Pattern																			
E	0.42	0.75	1.10	1.50	3.05	3.97	4.32*	4.24*	5.35	5.69*	6.75	5.69*	1.64	0.80	2.35	2.20	3.23	2.66	0.83
P	0.35	0.71	0.94	1.45	2.75	3.13	3.10	3.38	4.02	4.56	5.74	4.56	1.54	0.72	2.09	2.01	3.51	2.44	1.02
SE±	0.06	0.18	0.12	0.17	0.35	0.42	0.26	0.32	0.69	0.45	0.79	0.38	0.26	0.08	0.15	0.31	0.46	0.39	0.18
CD5%	NS	NS	0.25	0.37	0.75	0.89	0.57	0.69	1.47	0.96	1.70	0.83	NS	NS	0.33	NS	0.98	NS	NS

4.2.1.5.2 Stem:

The mean phytomass accumulation in groundnut stem increased with advance in crop age from 30 days (0.16, 0.34 and 0.32 g $plant^{-1}$) till the peak was attained at 120, 90 and 75 days (4.57, 3.35 and 3.13 g $plant^{-1}$) during summer 1983, 1984 and *kharif* 1983 respectively (Table 26).

The phytomass accumulation in stem was considerably reduced in groundnut intercropped with sunflower, particularly in the later stages following the pod formation. Sole crop of groundnut produced significantly higher phytomass from 60 days till harvest in the summer seasons. Similarly, in *kharif*, the stem in sole crop had a higher accumulation of phytomass and the differences were significant at all the samplings except at 30 and 60 days.

Planting method had no perceptible influence on the phytomass accumulation in stem. Though there was a significant difference at 90 days during summer 1984, the narrow and wide row treatments were equally effective at all the stages in the three seasons.

Equidistant rows in *kharif* indicated a numerical gain in weight while this trend was not persistent in the summer seasons. The differences at all the stages in any of the three seasons were too little to be detected significant except at harvest during summer, 1984.

[illegible] accumulation in [illegible] plant[illegible] of groundnut as influenced by different [illegible]

Treatment	30 Summer 1983	30 Summer 1984	45 Summer 1983	45 Summer 1984	60 Summer 1983	60 Summer 1984	75 Summer 1983	75 Summer 1984	90 Summer 1983	90 Summer 1984	105 Summer 1983	105 Summer 1984	120 Summer 1983	30 Kharif 1983	45 Kharif 1983	60 Kharif 1983	75 Kharif 1983	90 Kharif 1983	105 Kharif 1983
SNE	0.15	0.56	0.51	0.66	2.71	2.66	4.15	4.34	4.54	5.39	5.00	4.50	5.34	0.41	1.51	2.42	3.25	3.51	2.09
SNP	0.17	0.27	0.67	0.80	2.47	2.25	3.17	4.12	5.45	4.08	5.78	3.25	[illegible]	0.33	1.34	2.60	4.57	2.96	2.41
SWE	0.15	0.24	0.66	0.87	2.89	2.85	4.14	2.70	5.62	3.10	5.60	3.60	5.61	0.36	1.40	1.55	4.49	3.22	3.05
SWP	0.22	0.29	0.44	1.40	2.75	2.32	2.88	2.47	3.56	3.83	4.52	2.60	[illegible]	0.32	1.22	1.55	3.48	2.94	2.30
INE	0.11	0.33	0.48	0.82	0.75	1.29	1.25	1.99	1.97	2.35	2.00	1.47	2.21	0.26	1.12	2.36	2.50	1.78	1.85
INP	0.10	0.44	0.44	0.69	0.72	1.67	1.03	2.06	2.01	2.87	2.25	1.58	2.43	0.28	0.94	1.77	2.25	2.26	1.87
IWE	0.18	0.32	0.39	0.90	0.91	1.61	1.08	2.26	1.60	2.46	2.02	1.69	2.39	0.28	1.05	2.26	2.58	2.59	2.48
IWP	0.22	0.29	0.45	0.74	1.26	2.29	1.45	2.17	2.16	2.73	2.18	1.66	2.23	0.30	1.01	2.14	1.97	2.17	1.95
SE ±	0.05	0.17	0.15	0.26	0.41	0.64	0.53	0.65	1.58	0.53	1.40	0.31	1.31	0.07	0.15	0.68	0.97	0.61	0.37
CD 5%	NS	NS	NS	NS	0.88	NS	1.14	1.41	3.40	1.14	3.00	0.66	2.78	NS	0.33	NS	NS	NS	NS
Mean	0.16	0.34	0.50	0.86	1.80	2.12	2.39	3.01	3.61	3.35	3.67	2.54	4.57	0.32	1.20	2.08	3.13	2.55	2.25
S x M																			
SN	0.17	0.41	0.59	0.73	2.57	2.46	3.66	4.23	4.99	4.73*	5.39	3.88**	6.06	0.37	1.42	2.51	3.91	3.24	2.25
SW	0.18	0.27	0.55	1.13	2.82	2.59	3.51	2.58	4.59	3.47	5.06	3.10	5.62	0.34	1.31	1.55	3.98	3.08	2.67
IN	0.12	0.38	0.46	0.75	0.74	1.48	1.14	2.03	2.00	2.61	2.12	1.53	2.23	0.27	1.03	2.07	2.37	2.02	1.86
IW	0.20	0.31	0.42	0.82	1.09	1.95	1.27	2.23	1.88	2.60	2.10	1.67	2.31	0.29	1.03	2.20	2.28	2.38	2.21
S x P																			
SE	0.15	0.40	0.58	0.77	2.80	2.76	4.15	3.52	5.08	4.24	5.30	4.05**	5.52	0.39	1.45	1.98	3.87	3.37	2.57
SP	0.21	0.28	0.56	1.10	2.60	2.28	3.03	3.29	4.50	3.96	5.15	2.93	6.16	0.33	1.28	2.07	4.02	2.95	2.55
IE	0.14	0.32	0.43	0.86	0.83	1.45	1.16	2.13	1.78	2.41	2.01	1.58	2.21	0.27	1.08	2.31	2.54	2.18	2.16
IP	0.16	0.37	0.44	0.71	0.99	1.98	1.24	2.12	2.09	2.80	2.21	1.62	2.33	0.29	0.97	1.96	2.11	2.21	1.91
M x P																			
NE	0.13	0.44	0.49	0.74	1.73	1.98	2.70	3.17	3.26	3.87	3.50	2.99	3.71	0.34	1.31	2.39	2.87	2.65	1.97
NP	0.15	0.35	0.56	0.74	1.58	1.96	2.10	3.09	3.73	3.47	4.01	2.42	4.58	0.30	1.41	2.18	3.41	2.61	2.14
WE	0.16	0.28	0.52	0.89	1.90	2.23	2.61	2.48	3.61	2.78	3.81	2.64	4.02	0.32	1.22	1.90	3.53	2.90	2.76
WP	0.22	0.29	0.45	1.07	2.00	2.30	2.17	2.32	2.86	3.28	3.35	2.13	3.91	0.31	1.11	1.85	2.72	2.55	2.12
SE ±	0.04	0.12	0.11	0.18	0.29	0.45	0.38	0.46	1.12	0.38	0.99	0.22	0.92	0.05	0.11	0.48	0.69	0.43	0.26
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.81	NS	0.47	NS	NS	NS	NS	NS	NS	NS
System																			
S	0.18	0.34	0.57	0.93	2.70**	2.52*	3.59*	3.40**	4.79**	4.10**	5.22**	3.49**	5.84**	0.36	1.37**	2.03	3.94**	3.15*	2.46*
I	0.15	0.34	0.44	0.79	0.91	1.72	1.20	2.12	1.94	2.60	2.11	1.60	2.27	0.28	1.03	2.13	2.33	2.20	2.03
Method																			
N	0.14	0.40	0.52	0.74	1.65	1.97	2.40	3.13	3.49	3.67*	3.75	2.70	4.14	0.32	1.23	2.29	3.14	2.63	2.05
W	0.19	0.29	0.48	0.98	1.95	2.27	2.39	2.40	3.24	3.03	3.58	2.39	3.96	0.31	1.17	1.87	3.13	2.73	2.44
Pattern																			
E	0.15	0.36	0.51	0.81	1.82	2.10	2.66	2.82	3.43	3.32	3.65	2.81**	3.86	0.33	1.27	2.15	3.20	2.77	2.36
P	0.18	0.32	0.50	0.91	1.79	2.13	2.13	2.70	3.29	3.38	3.68	2.27	4.24	0.31	1.13	2.01	3.07	2.58	2.13
SE ±	0.02	0.08	0.08	0.13	0.20	0.32	0.27	0.33	0.79	0.26	0.70	0.15	0.65	0.04	0.08	0.34	0.49	0.31	0.18
CD 5%	NS	NS	NS	NS	0.44	0.68	0.61	0.70	1.70	0.57	1.50	0.33	1.40	NS	0.16	NS	1.04	0.66	0.39

The interaction effects were not significant in most instances. System and method of planting showed a significant interaction at 90 and 105 days while planting system interacted with planting pattern at harvest during summer, 1984.

4.2.1.5.3 Pods:

The mean dry weight of pods per plant increased consistently from 1.05 g at 75 days during summer, 1983 while from 0.23 g each at 60 days during summer 1984 and kharif 1983 to a maximum of 5.92, 8.76 and 3.22 g towards maturity during the respective seasons (Table 27).

Planting system had a profound influence on the pod weight per plant. Pods in intercropped groundnut weighed significantly less than the sole crop at every stage in the summer seasons. In kharif, monoculture manifested a significant increase over the intercropped groundnut at 75 days. In the subsequent samplings at 90 and 105 days though the sole crop outweighed pods in an intercrop system, the differences were not significant.

Planting method had no significant influence on the phytomass accumulation of pods. The crop sown in close proximity between the rows or distant apart accumulated statistically similar amount of phytomass in the pods.

Response to the row arrangement in equidistant/paired pattern similarly had no significant influence in altering the dry weight of pods per plant at any stage.

Table 27. Phytomass accumulation (g per plant) in pods of groundnut as influenced by different treatments

Treat - ment	Days after sowing											
	60	75		90		105		120	60	75	90	105
	Summer								Kharif			
	1984	1983	1984	1983	1984	1983	1984	1983	1983			
SNE	0.43	2.41	2.44	4.97	8.95	8.88	14.13	9.94	0.43	2.35	3.16	4.91
SNP	0.11	2.08	2.79	6.81	6.60	9.00	11.95	8.49	0.06	3.47	2.72	3.17
SWE	0.39	2.31	1.86	4.66	5.71	9.48	12.95	9.52	0.21	3.00	2.47	3.59
SWP	0.30	0.91	2.51	2.41	8.15	9.20	9.63	9.33	0.14	2.74	2.57	3.04
INE	0.03	0.29	1.51	1.20	4.70	2.42	5.90	2.17	0.30	0.85	2.02	2.99
INP	0.14	0.14	1.05	0.59	3.56	2.97	4.33	2.20	0.17	2.01	1.96	2.31
IWE	0.25	0.12	0.60	0.58	3.78	2.84	4.68	2.17	0.17	2.77	1.99	3.88
IWP	0.21	0.15	0.83	1.71	4.39	2.58	6.51	2.70	0.38	0.77	1.83	1.88
SE ±	0.14	0.58	0.59	1.20	1.27	1.92	1.91	1.74	0.26	0.61	0.86	1.08
CD 5%	NS	1.26	1.26	2.57	2.72	4.12	4.09	3.73	NS	1.30	NS	NS
Mean	0.23	1.05	1.70	2.83	5.73	5.92	8.76	5.81	0.23	2.24	2.19	3.22
S x M												
SN	0.27	2.24	2.62	5.74	7.78	8.94*	13.04*	9.21	0.24	2.91	2.94	4.04
SW	0.34	1.61	2.18	3.54	6.93	9.34	11.29	9.43	0.17	2.87	2.52	3.31
IN	0.08	0.21	1.28	0.90	4.13	2.69	5.12	2.18	0.24	1.43	1.99	2.65
IW	0.23	0.14	0.71	1.15	4.09	2.71	1.35	2.43	0.24	1.77	1.91	2.88
S x P												
SE	0.41	2.36	2.15	4.66	7.33	9.18	13.54	9.73	0.32	2.67	5.81	4.25
SP	0.20	1.49	2.65	4.61	7.38	5.94	10.79	8.91	0.10	3.11	2.65	3.10
IE	0.14	0.20	1.06	0.89	4.24	2.63	5.29	2.17	0.23	1.81	2.00	3.43
IP	0.18	0.15	0.94	1.15	3.97	2.77	5.42	2.45	0.28	1.39	1.89	2.09
M x P												
NE	0.23	1.35	1.98	2.94	6.82	5.65	10.02	6.05	0.37	1.60	2.59	3.95
NP	0.12	1.11	1.92	3.70	5.08	5.98	8.14	5.35	0.11	2.74	2.34	2.74
WE	0.32	1.21	1.23	2.62	4.75	6.16	8.81	5.85	0.19	2.88	2.23	3.73
WP	0.26	0.53	1.67	2.06	6.27	5.89	8.07	6.02	0.26	1.76	2.10	2.46
SE ±	0.10	0.41	0.42	0.85	0.90	1.36	1.35	1.23	0.18	0.43	0.61	0.76
CD 5%	NS	NS	NS	NS	NS	2.92	2.89	NS	NS	NS	NS	NS
System												
S	0.31*	1.92*	2.40*	4.64**	7.35*	9.14**	12.17**	9.32**	0.21	2.89*	2.73	3.68
I	0.16	0.17	1.00	1.02	4.11	2.70	5.36	2.31	0.26	1.60	1.95	2.76
Method												
N	0.18	1.23	1.95	3.32	5.95	5.81	9.08	5.70	0.24	2.17	2.46	3.35
W	0.29	0.87	1.45	2.34	5.51	6.02	8.44	5.93	0.22	2.32	2.16	3.09
Pattern												
E	0.27	1.28	1.60	2.78	5.79	5.90	9.41	5.95	0.28	2.24	2.41	3.84
P	0.19	0.82	1.79	2.88	5.68	5.93	8.11	5.68	0.19	2.25	2.18	2.60
SE ±	0.07	0.29	0.29	0.60	0.63	0.96	0.95	0.87	0.13	0.30	0.43	0.54
CD 5%	0.15	0.63	0.63	1.28	1.36	2.05	2.05	1.86	NS	0.65	NS	NS

None of the interactions except planting system and method at 105 days in the summer seasons during 1983 and 1984 were significant.

4.2.1.6 Number of pegs per plant

Considerable differences in the number of pegs per plant are apparent due to different treatments within each sampling stage in the three seasons (Table 28).

Peg formation was severely deterred in groundnut associated with sunflower. This reduction was significant relative to the monoculture at every sampling except at 105 and 120 days during summer 1983 while at 60 and 75 days during summer, 1984. In *kharif*, the monoculture had significantly more number of pegs per plant at 75 and 90 days while at other stages it was on par with the intercropped groundnut.

Number of pegs per plant remained virtually unaffected by the differential row widths irrespective of the growing season and the sampling period.

Equidistant row arrangement in *kharif* tended to incrase the number of pegs per plant at different stages of crop growth. But, this effect was significant only at 75 days. No definite trend, however, was observed in the summer seasons either during 1983 or 1984.

None of the interaction effects except method and pattern of planting at 90 days during summer 1983 while system

Table 28. Number of pods per plant of groundnut as influenced by different treatments

Treatment	Summer 60 DAS 1983	Summer 60 DAS 1984	Summer 75 DAS 1983	Summer 75 DAS 1984	Summer 90 DAS 1983	Summer 90 DAS 1984	Summer 105 DAS 1983	Summer 105 DAS 1984	Summer 120 DAS 1983	Kharif 1983 60	Kharif 1983 75	Kharif 1983 90	Kharif 1983 105
SNE	6.48	9.53	16.16	8.93	12.87	9.60	1[illegible].53	15.30	9.26	6.92	7.73	9.27	5.75
SNF	1.66	7.87	7.46	10.00	19.42	8.13	16.13	11.80	11.26	6.80	7.87	8.1[illegible]	5.25
SWE	5.45	7.67	12.03	7.40	17.60	9.87	14.73	8.45	8.66	11.20	10.73	7.33	5.87
SWP	5.60	7.13	13.40	10.00	11.60	10.00	14.26	11.26	5.66	9.20	7.22	6.47	4.07
INE	1.66	5.93	1.80	8.80	1.86	6.37	4.40	4.44	7.40	8.03	6.00	5.80	4.67
INP	1.40	6.24	3.85	5.47	4.82	3.83	5.93	5.33	5.06	7.60	3.00	5.43	6.40
IWE	1.72	5.20	3.05	10.77	2.18	7.57	8.06	7.22	6.93	10.00	7.77	5.60	5.73
IWP	1.93	9.47	2.42	7.07	3.60	8.33	9.98	6.95	3.60	7.73	3.77	3.80	4.95
SE±	1.71	1.66	2.08	1.77	3.08	2.66	3.00	3.80	2.95	2.07	1.86	1.61	1.29
CD5%	3.67	NS	4.46	NS	6.61	NS	6.45	NS	NS	NS	4.00	NS	NS
Mean	3.24	7.38	7.52	8.55	9.24	7.96	10.63	8.84	7.23	8.43	6.76	6.48	5.33
S x M													
SN	4.64	8.70	11.82	9.47	16.14	8.87	13.83	13.55	10.27	6.86	7.60	8.70	5.50
SW	5.52	7.40	12.72	8.70	14.60	9.93	14.50	9.85	7.17	10.20	9.04	6.90	4.97
IN	1.53	6.09	2.83	7.13	3.34	5.10	5.17	4.89	6.23	7.82	4.50	5.62	5.53
IW	1.82	7.33	2.73	8.92	2.89	7.95	9.02	7.09	5.27	8.87	5.77	4.70	5.34
S x P													
SE	5.97	8.60	14.10	8.17**	15.23	9.73	13.13	11.88	8.97	9.06	9.10	8.30	5.81
SP	4.20	7.50	10.43	10.00	15.51	9.07	15.20	11.53	8.47	8.00	7.54	7.30	4.66
IE	1.69	5.57	2.43	9.78	2.02	6.97	6.23	5.83	7.17	9.02	6.88	5.70	5.20
IP	1.67	7.85	3.13	6.27	4.21	6.08	7.96	6.14	4.33	7.67	3.38	4.62	5.67
M x P													
NE	4.07	7.73	8.98	8.87	7.37*	7.98	7.97	9.87	8.33	7.47	6.67	7.53	5.21
NP	2.10	7.05	5.66	7.73	12.12	5.98	11.03	8.57	8.17	7.20	5.43	6.78	5.82
WE	3.58	6.43	7.54	9.08	9.89	8.72	11.40	7.84	7.80	10.60	9.32	6.47	5.80
WP	3.77	8.30	7.91	8.53	7.60	9.17	12.12	9.10	4.63	8.47	5.49	5.13	4.51
SE ±	1.21	11.73	1.47	1.25	2.17	1.88	2.12	2.69	2.08	1.46	1.32	1.14	0.91
CD 5%	NS	NS	NS	2.69	5.22	NS	NS	NS	NS	NS	NS	NS	NS
System													
S	5.08**	8.05	12.27**	9.08	15.37**	9.40*	14.17	11.70**	8.72	8.53	8.32**	7.80**	5.23
I	1.68	6.71	2.78	8.02	3.11	6.52	7.10	5.99	5.75	8.34	5.13	5.16	5.44
Method													
N	3.09	7.39	7.32	8.30	9.74	6.98	9.50	9.22	8.25	7.34	6.05	7.16	5.52
W	3.67	7.37	7.73	8.81	8.77	8.94	11.76	8.47	6.22	9.53	7.40	5.80	5.15
Pattern													
E	3.83	7.08	8.26	8.97	8.63	8.35	9.68	8.85	8.07	9.04	7.99*	7.00	5.50
P	2.93	7.68	6.78	8.13	9.86	7.57	11.58	8.84	6.40	7.83	5.46	5.96	5.17
SE ±	0.86	0.83	1.04	0.89	1.54	1.33	1.50	1.90	1.47	1.03	0.93	0.80	0.64
CD 5%	1.84	NS	2.23	NS	3.30	2.85	NS	4.08	NS	NS	2.00	1.72	NS

and pattern of planting at 75 days during summer 1984 influenced the peg formation. The second order interactions were not significant at any stage.

4.2.1.7 Number of pods per plant

The mean number of pods per plant increased from 0.80 and 2.12 at 60 days during summer 1983 and 1984 to a maximum of 12.79 and 14.46 at harvest (Table 29). In *kharif* pod number rose steadily from 3.47 at 60 days to 10.23 at 75 days but declined subsequently to 5.43 $plant^{-1}$ at harvest.

Response to pod formation during the reproductive phase varied considerably by the planting system. Sole crop of groundnut registered significantly more number of pods per plant consistently at every sampling in the summer seasons except at 60 days during 1984. In *kharif*, the sole crop recorded significantly more number of pods at 75 and 90 days, while it was at par with the intercrop at 60 days and harvest.

Equidistant row arrangement had an edge over the paired rows in the *kharif* season. But this influence was not consistent in the summer seasons. However, the differences were not significant. Interactions between planting system and pattern were significant at 75 days during summer and *kharif* 1983.

4.2.1.8 Test weight (g)

The test weight of groundnut pods as influenced by different treatments are presented in Table 30. The mean test weight

Table 29. Number of pods per plant of groundnut as influenced by different treatments

Treatment	Days after sowing: Summer 60 (1983)	60 (1984)	75 (1983)	75 (1984)	90 (1983)	90 (1984)	105 (1983)	105 (1984)	120 (1983)	Kharif 1983: 60	75	90	105
SNE	1.33	2.07	7.20	6.93	8.86	[illegible]	15.00	19.87	19.13	4.13	7.53	6.23	5.47
SNP	0.66	2.20	4.71	7.13	12.02	[illegible]	21.73	13.53	17.30	1.13	11.20	4.60	5.40
SWE	0.80	2.32	6.28	4.73	8.60	9.00	21.40	19.94	19.06	3.20	9.80	4.53	6.91
SWP	2.62	3.80	4.80	7.20	5.60	12.00	19.60	15.94	17.46	2.47	10.50	4.60	4.00
INE	0.20	0.93	1.13	2.80	1.80	5.23	3.26	8.62	6.66	2.70	8.80	3.62	6.27
INP	0.10	2.13	2.41	3.40	2.46	5.57	5.00	12.30	6.70	2.40	19.20	3.32	5.27
IWE	0.25	1.87	0.53	2.10	0.88	6.46	4.86	14.37	7.47	4.13	10.00	3.67	7.33
IWP	0.49	1.68	1.07	3.07	4.27	7.37	8.53	11.11	8.53	2.65	4.82	4.01	3.85
SE ±	0.70	0.90	1.11	0.84	2.24	2.11	4.21	5.18	3.07	3.20	1.72	1.24	1.93
CD 5%	1.49	NS	2.39	1.81	4.80	4.53	9.04	NS	6.56	NS	3.70	NS	NS
Mean	0.80	2.12	3.51	5.92	5.56	8.57	12.42	14.46	12.79	3.47	10.23	4.32	5.43
S x M													
SN	1.00	2.13	5.95	7.03	10.44	11.47	18.37	16.70	18.21	5.13	9.37	5.43	5.43
SW	1.71	3.06	5.54	5.97	7.10	10.50	20.50	17.94	18.26	2.83	10.15	4.57	5.45
IN	0.51	1.53	1.77	3.10	2.13	5.40	4.13	10.46	6.68	2.55	7.10	3.47	5.77
IW	0.37	1.77	0.80	2.58	2.57	6.92	6.70	12.74	8.00	3.39	7.41	3.84	5.59
S x P													
SE	1.07	2.19	6.74*	5.83	8.73	11.13	18.20	19.90	19.10	3.67	8.67**	5.40	6.19
SP	1.64	3.00	4.75	7.17	8.81	10.83	20.67	14.74	17.38	1.80	10.85	4.60	4.70
IE	0.22	1.40	0.83	2.45	1.34	5.86	4.07	11.50	7.07	3.42	9.40	3.64	6.80
IP	0.29	1.91	1.74	3.23	3.37	6.47	6.77	11.70	7.62	2.52	5.11	3.66	4.56
M x P													
NE	0.77	1.50	4.17	4.87	5.33	9.25	9.13	14.24	12.90	3.42	8.17	4.94	5.87
NP	0.38	2.17	3.56	5.26	7.24	7.62	13.37	12.92	12.00	1.77	8.30	3.96	5.33
WE	0.52	2.09	3.41	3.42	4.74	7.74	13.13	17.16	13.27	3.67	9.90	4.10	7.12
WP	1.55	2.74	2.93	5.13	4.93	9.68	14.07	13.52	13.00	2.56	7.66	4.30	4.63
SE ±	0.49	0.63	0.79	0.59	1.58	1.49	2.98	3.64	2.16	2.26	1.22	0.88	1.37
CD 5%	NS	NS	1.69	NS	NS	NS	NS	NS	NS	NS	2.61	NS	NS
System													
S	1.35*	2.60	5.75**	6.50**	8.77**	10.98**	19.43**	17.32**	18.24**	2.73	9.76*	5.00*	5.44
I	0.26	1.65	1.29	2.84	2.35	6.16	5.42	11.60	7.34	2.97	7.25	3.65	5.68
Method													
N	0.57	1.83	3.86	5.06	6.29	8.43	11.25	13.58	12.45	2.59	8.23	4.45	5.60
W	1.04	2.42	3.17	4.27	4.84	8.71	13.60	15.34	13.13	3.11	8.78	4.20	5.52
Pattern													
E	0.65	1.80	3.79	4.14	5.04	8.50	11.13	15.70	13.08	3.66	9.03	4.52	6.49
P	0.97	2.45	3.25	5.20	6.09	8.65	13.72	13.22	12.50	2.16	7.98	[illegible]	4.63
SE ±	0.35	0.45	0.56	0.42	1.12	1.06	2.11	2.59	1.53	1.60	0.86	0.62	0.97
CD 5%	0.75	NS	1.19	0.90	2.40	2.27	4.52	5.56	3.28	NS	1.86	1.33	NS

in the summer seasons during 1983 and 1984 was 87.31 and 98.23g respectively. In the *kharif* season hundred pods on an average weighed 77.41 g.

Planting system had a profound influence on the test weight in each season. Hundred pods of groundnut in sole crop weighed 97.0, 100.72 and 83.66 g during summer 1983, 1984 and *kharif* 1983 respectively. The corresponding weight in inter-cropping system was significantly reduced to 77.62, 95.83 and 71.16 g.

The test weight in narrow and wider row treatments did not show a differential response in the three seasons.

Hundred pods in equidistant row arrangement weighed less (84.92 g) than in the paired rows (89.71g) during summer 1983. But, the differences were not significant. During summer 1984 and *kharif* 1983, equidistant row arrangement on the contrary registered a significant increase in the test weight over the paired row pattern.

None of the interactions were significant in the summer seasons. Interaction between planting system and pattern was however significant in the *kharif* season.

4.2.1.9 Shelling per cent

The mean shelling percentage in the summer seasons was more both during 1983 (71.3 g) and 1984 (73.4 g) than in *kharif* (57.9 g) season (Table 30).

Shelling percentage was not influenced either by the planting system, method or the pattern of row arrangements and their interaction in the summer seasons. But, in kharif shelling percentage was significantly more in sole groundnut (60.3 g) than in the intercrop system (55.5 g). Shelling percentage in the narrow row treatment (59.4 g) was also significantly superior to the wider row treatment (56.4 g) in this season. However, the influence of planting pattern was not significant. The first order interactions were significant between planting system and method as well as planting method and pattern.

4.2.1.10 Oil percentage

The mean oil percentage in the summer seasons during 1983 and 1984 was 42.8 and 41.0 respectively. In kharif it was 43.2% (Table 30).

Response to the planting system was significant during summer 1983. The kernels in sole crop of groundnut had significantly greater concentration of oil (43.8%) than in the intercrop system (41.9%). The first order interactions were significant in this season. But, during the subsequent kharif and summer seasons planting system did not influence the oil percentage nor it interacted with the planting method or row arrangement. Planting method as well as the planting pattern had no significant influence in any season.

Table 30. Test weight (g 100^{-1} pods), shelling per cent and oil per cent of groundnut as influenced by different treatments

Treatment	100-pod weight (g)			Shelling percent			Oil percent		
	Summer		Kharif	Summer		Kharif	Summer		Kharif
	1983	1984	1983	1983	1984	1983	1983	1984	1983
SNE	97.83	104.02	95.87	72.0	77.0	65.7	45.2	42.3	42.9
SNP	97.80	95.93	72.60	70.9	70.7	60.9	44.0	42.0	42.2
SWE	95.50	102.90	94.11	73.4	74.2	56.2	44.0	41.8	41.6
SWP	96.83	100.03	72.06	70.6	73.2	58.5	41.6	40.4	43.4
INE	70.00	98.27	71.43	70.4	71.3	56.3	39.2	40.4	45.0
INP	80.83	94.76	64.83	70.8	73.1	54.7	43.6	40.5	41.9
IWE	76.33	96.00	76.58	70.1	74.1	53.9	42.5	40.5	44.1
IWP	83.33	94.30	71.78	72.1	73.6	57.0	42.5	40.5	44.5
SE ±	4.90	3.22	5.49	2.8	3.3	2.6	1.1	1.9	1.9
CD 5%	10.51	NS	11.77	NS	NS	5.5	2.4	NS	NS
Mean	87.31	98.23	77.41	71.3	73.4	57.9	42.8	41.0	43.2
S x M									
SN	97.83	99.98	84.23	71.5	73.9	63.3*	44.6*	42.1	42.6
SW	96.17	101.47	83.09	72.0	73.7	57.3	42.8	41.1	43.4
IN	75.42	96.52	68.13	70.6	72.2	55.5	41.4	40.4	42.5
IW	79.83	95.15	74.18	71.1	73.9	55.4	42.5	40.5	44.3
S x P									
SE	96.67	103.46	94.99**	72.7	75.6	60.9	44.7**	42.0	42.3
SP	97.33	97.98	72.33	70.8	71.9	59.7	42.8	41.2	44.5
IE	73.17	97.13	74.00	70.3	72.7	55.1	40.9	40.4	42.8
IP	82.09	94.53	68.31	71.4	73.3	55.9	43.0	40.5	43.2
M x P									
NE	83.92	101.14	83.65	71.3	74.2	61.0*	42.2*	41.3	44.0
NP	89.33	95.35	68.72	70.8	71.9	57.8	43.8	41.2	42.9
WE	85.92	99.45	85.35	71.8	74.2	55.0	43.3	41.1	42.0
WP	90.09	97.17	71.92	71.4	73.4	57.7	42.1	40.4	43.9
SE ±	3.46	2.28	3.88	2.0	2.4	1.8	0.8	1.3	1.4
CD 5%	NS	NS	8.32	NS	NS	3.9	1.7	NS	NS
System									
S	97.00**	100.72**	83.66**	71.8	73.8	60.3**	43.8**	41.6	42.5
I	77.62	95.83	71.16	70.9	73.0	55.5	41.9	40.5	43.9
Method									
N	86.62	98.24	76.18	71.1	73.0	59.4*	43.0	41.3	43.0
W	88.00	98.31	78.63	71.5	73.8	56.4	42.7	40.8	43.4
Pattern									
E	84.92	100.30*	84.50**	71.5	74.2	58.0	42.8	41.2	43.4
P	89.71	96.26	70.32	71.1	72.6	57.8	42.9	40.8	43.0
SE ±	2.45	1.61	2.74	1.4	1.7	1.3	0.6	0.9	1.0
CD 5%	5.25	3.45	5.88	NS	NS	2.7	1.2	NS	NS

4.2.1.11 <u>Pod yield</u> (kg ha^{-1})

Average pod yield of groundnut was substantially low (587.26 kg ha^{-1}) in the *kharif* season than in summer during 1983 (1437.35 kg ha^{-1}) and 1984 (1901.54 kg ha^{-1}). The treatments exerted a significant influence on the pod yield in each season (Table 31).

Planting system influenced the pod yield of groundnut significantly. Groundnut in intercrop system yielded significantly less (855.76 and 1422.98 kg ha^{-1}) than the sole crop (2018.93 and 2380.09 kg ha^{-1}) in the summer seasons during 1983 and 1984. In *kharif*, the sole crop of groundnut similarly performed better, with a pod yield of 633.75 kg ha^{-1} as against 540.77 kg ha^{-1} when intercropped with sunflower. Despite an absolute yield reduction in the intercrop, differences in the pod yield however, were not significantly different from the sole crop.

Planting method had no influence on the pod yield of groundnut. The yields obtained from narrow row treatment (1513.90, 1850.66 and 561.78 kg ha^{-1}) were statistically on a par with the wider row plantings (1360.79, 1952.41 and 612.75 kg ha^{-1}) in the three seasons.

Planting pattern had a profound influence on pod yield. The equidistant row treatments registered an yield of 1547.73, 2245.69 and 672.88 kg ha^{-1} in the summer seasons during 1983, 1984 and *kharif* 1983 respectively. Corresponding yields in the paired row pattern on the other hand were reduced to 1326.95, 1557.38 and 501.64 kg ha^{-1}. The yield differences between the two treatments were not significant during summer, 1983 while, they were highly significant during summer, 1984 and kharif, 1983.

Planting system and pattern alone interacted significantly during summer, 1984, while none in the other seasons.

The pooled analysis of variance for mean yield over the summer seasons indicated a critical variation by the planting system and the pattern of row arrangement. Reduction in pod yield of groundnut intercropped with sunflower was highly significant. The sole crop registered a mean yield of 2199.88 kg pods ha^{-1} in contrast to 1139.38 kg ha^{-1} when intercropped.

Planting method showed that the mean yield of pods in narrow (1682 kg ha^{-1}) and wider row widths (1656.60 kg ha^{-1}) were statistically at par.

Planting pattern, conversely, had a highly significant influence. The equidistant rows registered an average yield of 1896.71 kg ha^{-1}, while the paired row pattern resulted in a substantial decline to 1442.17 kg pods ha^{-1}. Planting system and pattern interacted significantly.

4.2.1.12 Oil yield (kg ha^{-1})

The mean oil yield was fairly high in the summer seasons during 1983 (451.32 kg ha^{-1}) and 1984 (581.66 kg ha^{-1}) than in *kharif* (146.35 kg ha^{-1}) during 1983. Different treatments exerted a significant influence on the oil content in the three seasons (Table 31).

The influence of planting system on the oil yield of groundnut was highly significant in the summer seasons. The sole crop registered an oil content of 647.34 kg ha^{-1} in the summer season during 1983 and 739.68 kg ha^{-1} during 1984. The oil yield of groundnut sown in association with sunflower was drastically reduced to 255.31 and 422.73 kg ha^{-1} during the respective years. Intercropped groundnut in the *kharif* season similarly experienced a significant reduction in the oil yield (131.24 kg ha^{-1}) compared to the sole crop (161.45 kg ha^{-1}).

Planting method on the other hand did not influence the oil yield in any season. The oil yield both from the narrow (483.11, 571.39 and 145.18 kg ha^{-1}) and wider row (419.55, 591.03 and 147.51 kg ha^{-1}) treatments was statistically on par in the three seasons.

Equidistant planting pattern registered an oil content of 497.62 and 697.17 kg ha^{-1} in the summer seasons during 1983 and 1984, while, it was 169.81 kg ha^{-1} in the *kharif* season during 1983. The oil yield in paired row pattern was significantly reduced to 405.04, 465.25 and 122.89 kg ha^{-1} during the corresponding seasons.

Among the first order interactions, planting system and pattern had a significant influence in the summer seasons.

Table 31. Pod and oil yield (kg ha^{-1}) of groundnut as influenced by different treatments

Treatment	Pod yield kg ha^{-1}				Oil yield kg ha^{-1}			
	Summer		Pooled	Kharif	Summer		Pooled	Kharif
	1983	1984		1983	1983	1984		1983
SNE	2449.44	3027.28	2738.36	776.64	836.87	994.04	915.45	214.94
SNP	1934.17	1749.45	1841.81	492.75	605.50	522.56	564.03	126.06
SWE	2060.56	2948.64	2504.60	698.96	665.34	911.03	788.18	163.26
SWP	1631.54	1794.98	1713.26	566.65	481.64	534.70	508.17	136.55
INE	856.04	1474.81	1165.42	517.75	240.23	426.25	333.24	129.44
INP	815.94	1151.10	983.52	459.95	249.82	346.30	298.06	105.28
IWE	824.90	1532.04	1178.47	698.16	248.00	460.95	354.47	166.58
IWP	926.18	1534.00	1230.09	487.22	283.19	457.44	370.31	123.66
SE ±	252.52	207.90	180.18	102.00	80.03	88.90	103.59	27.82
CD 5%	541.65	445.95	NS	218.79	171.67	190.70	NS	59.67
Mean	1437.35	1901.54	1669.44	587.26	451.32	581.66	516.49	146.35
S x M								
SN	2191.80	2388.36	2290.83	634.70	721.19	756.50	739.85	173.00
SW	1846.05	2371.81	2108.93	632.80	573.49	722.86	648.18	149.90
IN	835.99	1312.95	1074.47	488.86	245.02	386.27	315.65	117.36
IW	875.54	1533.02	1204.28	592.69	265.60	459.19	362.40	145.12
S x P								
SE	2255.00	2987.96**	2621.48**	737.80	751.11*	950.74**	851.92**	191.60
SP	1782.85	1772.22	1777.53	529.70	543.57	528.63	536.10	131.30
IE	840.47	1503.42	1171.95	607.96	244.12	443.60	343.86	148.00
IP	871.06	1342.55	1106.80	473.59	266.50	401.87	334.19	114.47
M x P								
NE	1652.74	2251.04	1951.89	647.20	538.55	708.35	624.45	174.69
NP	1375.05	1450.28	1412.66	476.35	427.66	434.43	431.04	115.67
WE	1442.73	2240.34	1841.53	698.56	456.68	685.99	571.33	164.92
WP	1278.86	1664.49	1471.67	526.93	382.41	496.07	439.24	130.10
SE ±	178.56	147.00	127.40	72.12	56.59	62.87	73.25	19.67
CD 5%	NS	315.33	260.93	NS	121.40	134.85	150.02	NS
System								
S	2018.93**	2380.09**	2199.88**	633.75	647.34**	739.68**	694.00**	161.45*
I	855.76	1422.98	1139.38	540.77	255.31	422.73	339.02	131.24
Method								
N	1513.90	1850.66	1682.28	561.78	483.11	571.39	527.75	145.18
W	1360.79	1952.41	1656.60	612.75	419.55	591.03	505.29	147.51
Pattern								
E	1547.73	2245.69**	1896.71**	672.88**	497.62*	697.17**	597.89**	169.81**
P	1326.95	1557.38	1442.17	501.64	405.04	465.25	435.14	122.89
SE ±	126.26	103.95	90.09	51.00	40.02	44.45	51.79	13.92
CD 5%	270.83	222.97	184.50	109.40	85.84	95.35	105.82	29.84

The higher order interactions did not influence the oil yield significantly in any season.

The out-turn of oil on the basis of average production over two years in the summer seasons indicated a highly significant effect of planting system and the planting pattern. The mean oil yield from sole crop was 694.00 kg ha^{-1} in contrast to 339.02 kg ha^{-1} when intercropped.

Planting method did not alter the oil yield considerably since with narrow and wider row width treatments it averaged 527.75 and 505.29 kg ha^{-1} with no significant variation.

The equidistant row treatments resulted in a highly significant increase in the quantity of oil (597.89 kg ha^{-1}) than the paired row pattern (435.14 kg ha^{-1}). The interaction between planting system and pattern was highly significant.

4.2.1.13 Haulm yield (Kg ha^{-1})

The mean yield of haulms in the summer seasons during 1983 (3091.13 kg ha^{-1}) and 1984 (2486.13 kg ha^{-1}) were fairly high than in *kharif* (1807.78 kg ha^{-1}). The treatment effects were not significant in any of the three seasons (Table 32).

Planting system showed that the sole crop of groundnut registered higher yield of haulms (3373.12, 2808.90 and 1904.22 kg ha^{-1}) than in intercrop system (2809.14, 2163.36 and 1711.85 kg ha^{-1}) consistently in the three seasons. But, this effect was significant only during summer 1984.

Table 32. Haulm yield (kg ha^{-1}) of groundnut as influenced by different treatments

Treatment	Haulm yield kg ha^{-1}		
	Summer		Kharif
	1983	1984	1983
SNE	4619.39	3559.60	1941.60
SNP	3439.71	2191.82	1839.85
SWE	3025.66	3236.00	2346.10
SWP	2407.74	2248.17	1487.32
INE	1715.08	2143.74	1982.05
INP	2887.75	2015.83	1479.88
IWE	3413.98	2394.64	1860.70
IWP	3219.76	2099.23	1524.78
SE ±	1010.29	518.70	344.62
CD 5%	NS	NS	NS
S x M			
SN	4029.55	2875.71	1890.72
SW	2716.69	2742.08	1917.71
IN	2301.42	2079.79	1730.96
IW	3316.87	2246.94	1692.74
S X P			
SE	3822.52	3397.80	2143.85
SP	2923.72	2219.99	1664.58
IE	2564.53	2269.19	1921.37
IP	3053.76	2057.53	1502.33
M x P			
NE	3167.23	2851.67	1961.82
NP	3163.73	2103.82	1659.86
WE	3219.82	2815.32	2103.40
WP	2813.75	2173.70	1507.05
SE ±	714.38	366.78	243.68
CD 5%	NS	NS	NS
System			
S	3373.12	2808.90*	1904.22
I	2809.14	2163.36	1711.85
Method			
N	3165.48	2477.75	1810.84
W	3016.78	2494.51	1805.22
Pattern			
E	3193.53	2833.50*	2032.61*
P	2988.74	2138.76	1583.46
SE ±	505.15	259.35	172.31
CD 5%	NS	556.31	369.61

Planting method did not influence the haulm yield in any season. The narrow (3165.48, 2477.75 and 1810.84 kg ha^{-1}) and wider row (3016.78, 2494.51 and 1805.22 kg ha^{-1}) treatment effects were statistically on par in each season.

The equidistant row pattern (3193.53, 2833.50 and 2032.61 kg ha^{-1}) yielded higher quantity of haulms than the paired rows (2988.74, 2138.76 and 1583.46 kg ha^{-1}) in the three seasons. The treatment effects were however significant only during summer 1984 and kharif 1983 while, none of the interactions were significant in the three seasons.

4.2.2 Neutro-periodism

4.2.2.1 Per cent nutrient composition

The nutrient concentration of leaves, stem and pods as influenced by different treatments are presented separately for each of the three elements viz., nitrogen, phosphorus and potassium.

4.2.2.1.1 Nitrogen per cent

The concentration of nitrogen in different plant parts indicated that the absorption of this element continued upto 90 days after sowing (Fig. 10). Leaf and stem nitrogen attained two peaks of absorption coinciding with 45 and 90 days after sowing. However, leaf nitrogen in intercropped groundnut had its peak moved to 75 days in the summer seasons. Nitrogen in the pods increased upto 90 days and declined thereafter at maturity.

Analysis of variance indicated that the planting system had a perceptible influence on the nitrogen per cent of each plant part. Monoculture, consistently recorded a greater concentration in the leaves, stem and pods althrough the sequential samplings. However, the increase in the leaf nitrogen was not significantly different from the intercropped groundnut at 30, 45 and 75 days during summer 1983, at 75 days during summer 1984 and at 105 days during *kharif*, 1983. Stem nitrogen in monoculture was significantly superior at every sampling except at 30 days in the summer seasons and at 90 and 105 days in *kharif*. Pods in sole crop of groundnut similarly excelled over the intercrop with significant differences in the summer seasons. Groundnut pods in intercrop system likewise had relatively lower concentration of nitrogen than in the sole crop even in *kharif* season. But, the differences were not significant except at harvest.

Plànting method did not influence the nitrogen concentration of any plant part whether the crop was sown in narrow or wide rows. The absolute differences by a change in the row width were too little to be demarcated significantly different.

Groundnut in equidistant planting pattern tended to accumulate higher concentrations of nitrogen in each plant part. But, this favourable influence was statistically offset by the relatively small differences.

Response to the first as well as the second order interactions were not observed in any season.

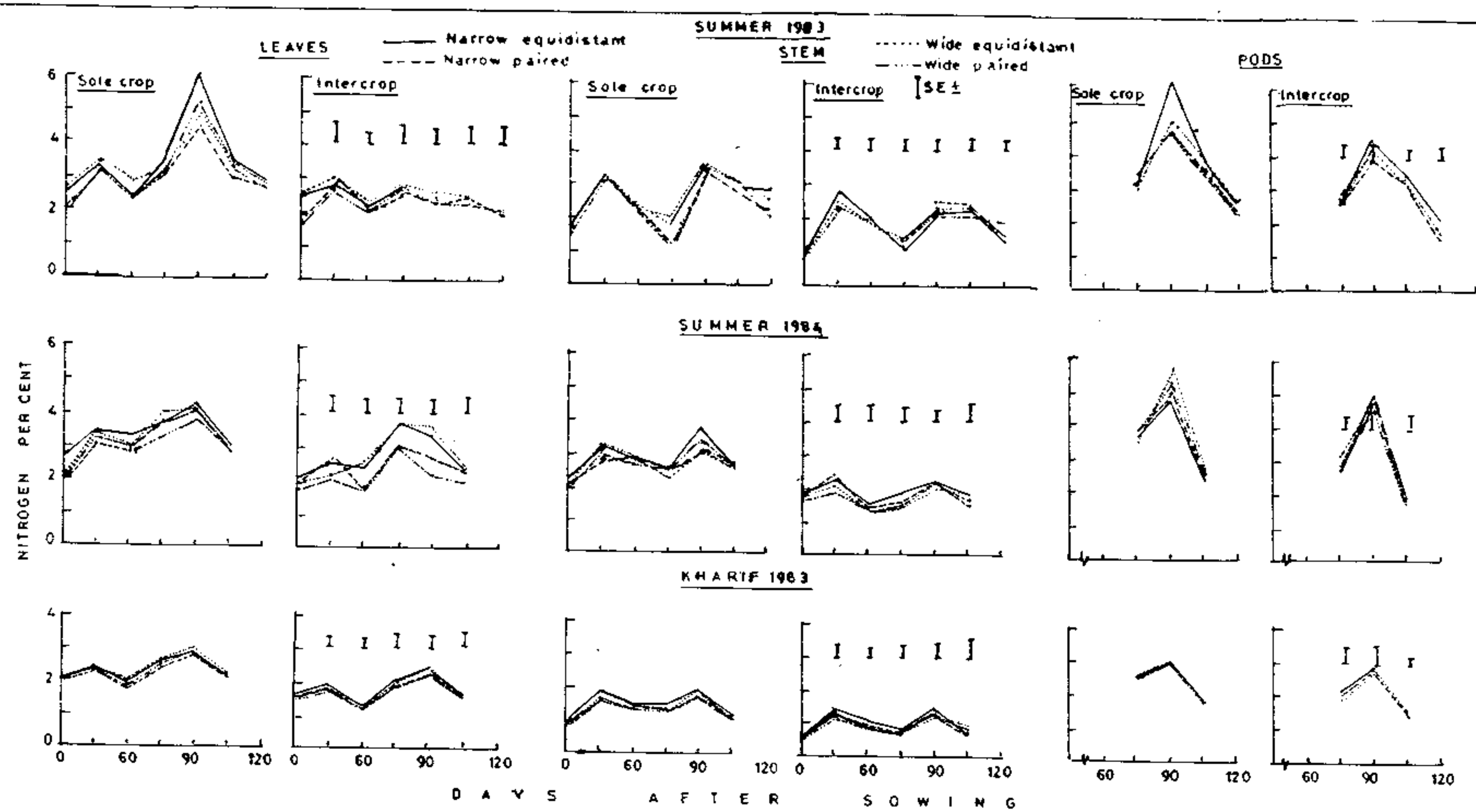


Fig:10- NITROGEN PER CENT IN PLANT PARTS OF GROUNDNUT AS INFLUENCED BY PLANTING GEOMETRY IN SOLE AND INTERCROP SYSTEM

4.2.2.1.2 **Phosphorus per cent**

The pattern of phosphorus absorption by leaves and stem per plant over the crop growth period was alike in the three seasons. It increased with crop age till the maximum values were attained at 60 days, but declined subsequently till harvest. Pods on the other hand had the greatest concentration in the initial phase of their development at 75 days followed by a rapid decline towards maturity. In summer and *kharif* season during 1983, phosphorus concentration followed a steep decline from 75 to 90 days and then decreased gradually towards maturity. During summer 1984 the decline was linear from 75 days till harvest (Fig. 11).

Groundnut in monoculture favoured excess concentration of phosphorus in the leaves, stem and pods than in the intercrop. But, this effect was not statistically significant at most of the samplings. The sole crop had significantly higher concentration of phosphorus in the leaves at 30 days during summer, 1983 at 30 and 45 days during summer 1984 and at 30, 75 and 90 days during *kharif* 1983. The concentration of phosphorus in stem and pods of the sole crop was significant only during summer 1983 at 45 and 75 days respectively.

Planting method virtually had no influence on the concentration of phosphorus. None of the above ground plant parts presented a significant contrast by the changed row-width in any season.

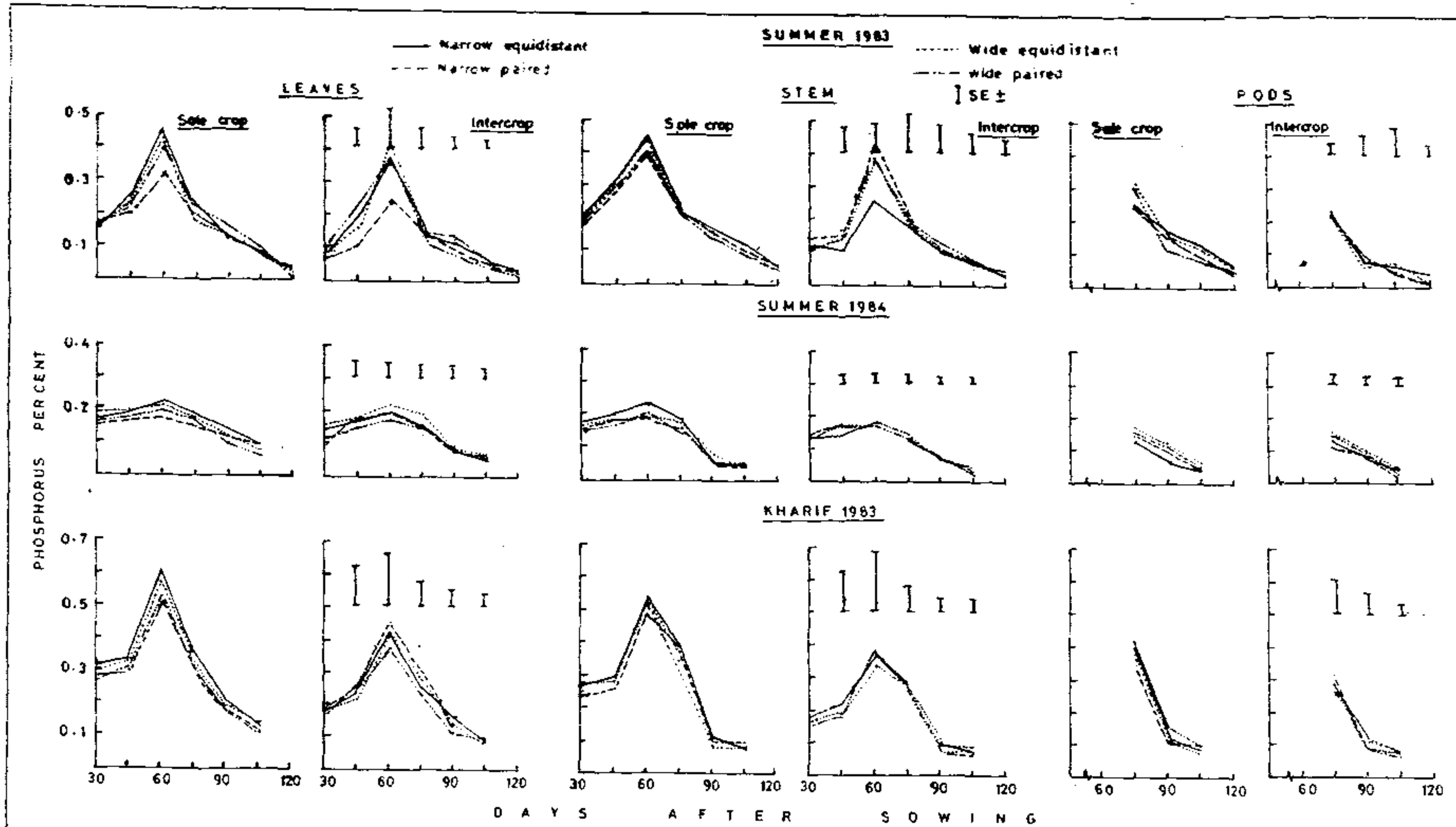


Fig:11- PHOSPHORUS PERCENT IN PLANT PARTS OF GROUNDNUT AS INFLUENCED BY PLANTING GEOMETRY IN SOLE AND INTERCROP SYSTEM

Planting pattern similarly, did not alter the per cent constituent of phosphorus by an equidistant or paired row arrangement for any plant part.

None of the treatment effects interacted significantly at any stage during the three seasons.

4.2.2.1.3 **Potassium per cent**

The concentration of potassium in the leaves and stem decreased from 30 to 45 days, but improved subsequently and in general approximately plateaued from 60 to 90 days. This improvement, however, was linear from 45 to 90 days in the intercropped groundnut during kharif 1983. Potassium concentration then indicated a rapid fall-off from 90 days till maturity. The behaviour of pods was distinctly different from the leaves and stem. The concentration of this element was maximum in the pods at 75 days which declined abruptly with further development of pods upto 90 days and then remained almost constant with little decline thereafter (Fig. 12).

Like phosphorus, the concentration of potassium in the leaves, stem and pods was little influenced by the planting system while the sole crop in general had an edge over the intercrop. The tissue concentration of potassium in leaves of the sole crop was significant only at 30 days during summer 1983 while that of in stem at 30, 60 and 90 days during kharif 1983.

The effect of planting method or pattern was not substantial as to significantly influence the concentration

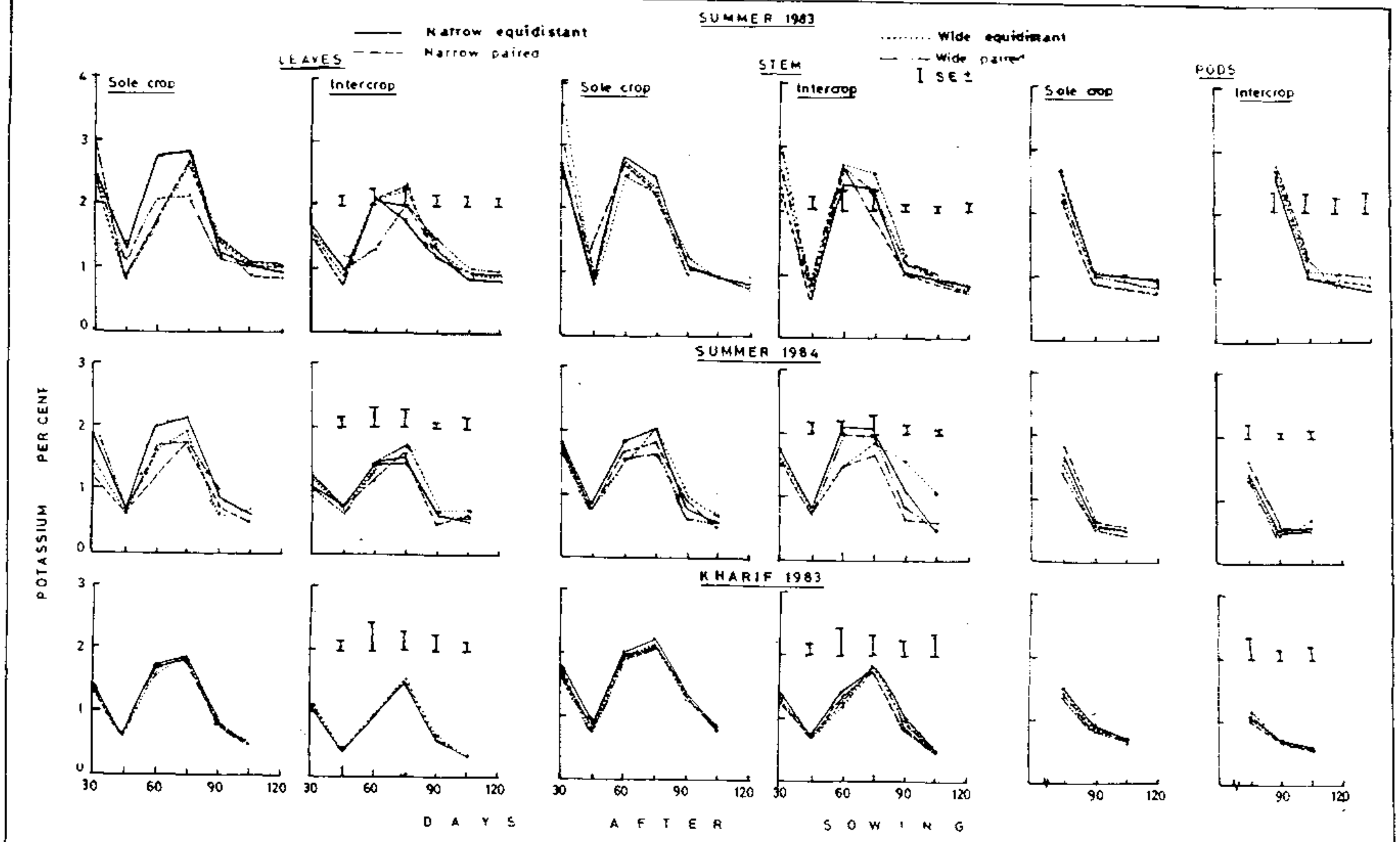


Fig:12- POTASSIUM PER CENT IN PLANT PARTS OF GROUNDNUT AS INFLUENCED BY PLANTING GEOMETRY IN SOLE AND INTERCROP SYSTEM of potassium in any plant part. The interactions were also not significant.

4.2.2.2 Nutrient uptake

The uptake of nitrogen, phosphorus and potassium by the plant components as influenced by the spatial configuration in a sole and intercropped system of groundnut are presented for each element separately.

4.2.2.2.1 Nitrogen

a. **Leaves:** The pattern of nitrogen removed by leaves in relation to the different treatments are presented in Table 33. The mean uptake increased consistently from 30 days (8.4 and 16.0 mg plant^{-1}) till the maximum was attained 90 days after sowing (209.7 and 177.1 mg plant^{-1}) during the summer seasons. In kharif the mean uptake increased from 30 (13.9 mg plant^{-1}) to 45 days (46.1 mg plant^{-1}) and declined at 60 days (33.2 mg plant^{-1}) but improved again with the peak being attained at 75 days (77.0 mg plant^{-1}). The uptake, then declined gradually diminishing towards maturity.

Planting groundnut as a sole crop or in a mixed stand with sunflower presented an enormous variation in the amount of nitrogen accumulated in the leaves. The uptake in sole crop significantly exceeded the amount of nitrogen removed by the leaves in intercrop system at every stage of sampling barring the initial stage at 30 days during the summer seasons. Similarly, in kharif, the sole crop removed significantly higher proportions of nitrogen at different stages of crop growth

Table 33. Nitrogen uptake (mg per plant) by the leaves of groundnut as influenced by different treatments

Treat-ment	Days after sowing																		
	30		45		60		75		90		105		120	30	45	60	75	90	105
	Summer													Kharif					
	1983	1984	1983	1984	1983	1984	1983	1984	1984	1984	1983	1984	1984	1983					
SNE	13.6	32.7	46.5	57.4	112.5	157.8	216.4	249.1	419.2	336.5	327.1	147.5	52.9	18.0	62.8	58.2	82.6	89.7	14.5
SNP	6.8	12.6	38.3	50.6	96.0	117.5	146.8	184.9	316.6	196.5	246.8	109.6	46.1	13.9	54.8	41.5	120.8	94.4	21.3
SWE	10.4	16.5	52.4	65.3	130.5	147.3	254.6	224.6	431.8	205.1	283.5	167.6	47.8	18.0	57.4	39.4	98.0	71.7	19.7
SWP	7.2	13.2	27.5	62.1	115.0	109.5	143.5	158.8	231.6	185.7	251.5	94.0	47.5	16.1	51.5	34.3	111.8	62.7	15.2
INE	9.0	10.7	22.8	25.2	30.5	72.3	46.5	82.0	79.9	111.8	88.9	64.0	33.6	10.6	48.2	23.0	53.2	45.4	9.9
INP	5.3	16.0	22.1	21.3	21.4	38.8	37.5	43.3	66.1	86.7	71.9	51.5	27.7	9.0	30.9	20.6	47.0	37.9	22.8
IWE	8.9	13.2	22.5	35.8	41.1	79.2	70.2	83.5	76.0	173.8	128.7	87.8	31.5	14.3	29.4	22.6	61.9	78.6	23.8
IWP	6.0	13.0	18.2	21.5	29.9	44.8	48.8	66.5	56.8	120.4	99.0	68.9	27.6	11.8	33.6	25.7	40.8	58.9	17.5
SE±	2.2	6.3	4.5	11.4	11.0	28.7	16.1	39.7	32.8	40.4	49.8	28.7	13.5	4.6	13.9	11.9	22.5	23.9	8.1
CD 5%	4.7	NS	9.6	24.4	23.5	61.5	34.4	85.1	70.3	86.8	106.9	61.7	NS	NS	NS	NS	NS	NS	NS
Mean	8.4	16.0	31.3	42.4	72.1	95.9	120.5	136.6	209.7	177.1	187.2	98.9	39.3	13.9	46.1	33.2	77.0	67.4	17.3
S x M																			
SN	10.2	22.6	42.4	54.0	104.1	137.6	181.6	217.0	367.9	266.5**	286.9	128.5	49.5	15.9	58.8	49.8	71.6	92.0	17.9
SW	8.8	14.8	39.9	63.7	122.7	128.4	199.0	191.7	331.7	195.4	267.5	114.2	47.6	17.0	54.4	36.8	104.9	67.2	17.4
IN	7.1	13.3	22.4	23.2	25.9	55.5	42.0	62.6	73.0	85.2	80.4	57.7	30.6	9.8	39.5	21.8	50.1	41.6	16.8
IW	7.4	13.1	20.3	28.6	35.5	62.0	59.5	75.0	66.4	147.1	113.8	78.3	29.5	13.0	31.5	24.1	51.3	68.7	20.6
S x P																			
SE	12.0	24.6	49.4**	61.3	121.4	152.5	235.5**	236.8	425.5**	270.8	305.3	140.9	50.3	18.0	60.1	48.8	90.3	80.7	17.1
SP	7.0	12.9	32.9	56.3	105.5	113.5	145.1	171.8	274.1	191.1	249.1	101.8	46.8	15.0	53.1	37.9	86.2	78.5	18.2
IE	8.9	11.9	22.6	30.5	35.8	75.7	58.3	82.7	77.9	128.7	108.8	75.9	32.5	12.4	38.8	22.8	57.5	62.0	17.3
IP	5.6	14.5	20.1	21.4	25.6	41.8	43.1	54.9	61.4	103.5	85.4	60.2	27.6	10.4	32.2	23.1	43.9	48.4	20.1
M x P																			
NE	11.3	21.7*	34.6*	41.3	71.4	115.0	131.4	165.5	249.5	210.1	208.0	105.7	43.2	14.3	55.5	40.6	67.9	67.5	12.7
NP	6.0	14.3	30.2	35.9	58.7	78.1	92.1	114.1	191.3	141.6	159.3	80.5	36.9	11.4	42.8	31.0	53.8	66.1	22.0
WE	9.6	14.8	37.4	50.5	85.8	113.2	162.4	154.0	253.9	189.4	206.1	111.1	39.6	16.1	43.4	31.0	79.9	75.1	21.7
WP	6.6	13.1	22.8	41.8	72.4	77.1	96.1	112.6	144.2	153.0	175.2	81.4	37.5	13.9	42.5	30.0	76.3	60.8	16.3
SE ±	1.5	4.5	3.2	8.0	7.7	20.3	11.3	28.0	23.2	28.6	35.2	20.3	9.6	3.2	9.8	8.4	15.9	36.3	5.7
CD 5%	NS	9.6	6.8	NS	NS	NS	24.4	NS	49.7	61.3	NS	NS	NS	NS	NS	NS	NS	NS	NS
System																			
S	9.5	18.7	41.2**	58.8**	113.4**	133.0**	190.3**	204.3**	349.8**	230.9**	277.2**	121.3**	48.6*	16.5*	56.6**	43.3**	88.2**	79.6	17.7
I	7.3	13.2	21.4	25.9	30.7	58.8	50.7	68.8	69.7	116.1	97.1	68.0	30.1	11.4	35.5	23.0	50.7	55.2	18.7
Method																			
N	8.7	18.0	32.4	38.6	65.0*	96.6	111.6*	139.8	220.4	175.8	183.7	93.1	40.1	12.9	49.2	35.8	60.8	66.8	17.4
W	8.1	14.0	30.1	46.2	79.1	95.2	129.3	133.3	199.0	171.2	190.7	96.2	38.6	15.0	43.0	30.5	78.1	68.0	19.0
Pattern																			
E	10.5**	18.3	36.0**	45.9	78.6*	114.1*	146.9**	159.8*	251.7**	199.8	207.0	108.4	41.4	15.2	49.4	35.8	73.9	71.3	17.2
P	6.3	13.7	26.5	38.9	65.6	77.6	94.1	113.4	167.8	147.3	167.3	81.0	37.2	12.7	42.7	30.5	65.0	63.5	19.2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CD 5%	2.4	NS	4.8	12.2	11.8	30.8	17.2	[illegible]	[illegible]	43.7	53.4	30.8	14.5	4.9	14.9	12.8	24.1	NS	NS

but did not differ significantly from the nutrient removed by the intercrop in the later stages at 90 and 105 days.

Planting method did not influence the accumulation of nitrogen in the leaves. Narrow row treatments compared favourably with the wider rows with no significant contrast at any stage except at 60 and 75 days during summer 1983.

Equidistant row arrangement resulted in higher amount of nitrogen being removed by the leaves at every sampling in the summer seasons. This effect was significantly superior to the paired rows at all the stages of crop growth except at 105 and 120 days during summer 1983. During summer 1984 the equidistant row treatments were significantly superior at 60 and 75 days. In the *kharif* season this treatment generally tended to supercede the paired rows, but, did not differ significantly at any stage.

Planting system and method interacted at 90 days during summer 1984, planting system and pattern at 45, 75 and 90 days during summer 1983, while method and pattern at 45 days during summer 1983 and at 30 days during summer 1984. The second order interactions were not significant. In *kharif* none of the treatment effects interacted to significantly vary the nitrogen uptake at any stage.

b. Stem: The course of nitrogen uptake in the stem (Table 34) followed an identical pattern of increasing to a maximum from 30 days after sowing (2.2, 6.4 and 2.3 mg plant^{-1}) upto 90 days (105.8, 98.9 and 45.9 mg plant^{-1}) and then declining

Table 34. Nitrogen uptake (mg per plant) by the stem of groundnut as influenced by different treatments

Treat-ment	Days after sowing 30		45		60		75		90		105		120	30	45	60	75	90	105
	Summer													Kharif					
	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984	1983	1983					
SNE	2.5	11.9	15.8	21.1	64.8	72.9	74.7	109.4	163.0	202.1	152.0	120.6	135.8	4.0	27.8	37.0	46.1	67.4	25.9
SNP	2.9	4.9	20.4	24.2	55.4	59.6	36.5	104.3	188.6	137.9	169.4	84.8	135.3	2.9	23.0	36.9	59.0	55.4	27.0
SWE	2.1	4.7	25.9	27.6	67.9	77.8	82.4	61.8	194.5	100.8	167.4	95.0	159.5	3.3	25.3	22.8	60.2	63.4	36.0
SWP	3.3	5.5	14.2	40.3	63.8	63.6	57.9	65.0	117.8	121.4	125.7	65.8	125.2	2.7	26.8	22.5	47.3	51.7	26.2
INE	1.1	6.2	13.3	18.8	13.8	19.7	14.0	37.2	44.5	52.4	45.6	27.3	32.3	1.5	16.2	26.4	22.0	27.4	16.1
INP	1.1	7.3	10.0	12.6	13.7	24.0	13.7	34.2	46.0	67.4	47.6	28.1	46.4	1.6	12.8	17.0	16.6	33.4	13.5
IWE	1.8	5.7	9.5	19.2	16.5	22.2	15.1	33.9	37.6	50.1	46.9	30.9	32.5	1.4	13.5	21.5	21.2	36.8	22.8
IWP	2.6	5.3	11.2	18.1	23.1	33.0	18.0	36.0	54.2	59.0	53.4	26.2	35.6	1.4	14.9	23.5	15.4	31.7	13.8
SE±	0.5	3.3	4.6	11.5	10.1	13.8	7.5	22.6	25.0	27.5	37.3	22.9	34.0	0.7	7.4	11.2	12.3	15.5	7.1
CD5%	1.1	NS	NS	NS	21.7	29.7	16.1	48.4	53.6	59.1	80.0	49.2	73.0	1.6	NS	NS	26.3	NS	NS
Mean	2.2	6.4	15.0	25.2	39.9	46.6	39.0	60.2	105.8	98.9	101.0	59.8	87.8	2.3	20.0	25.9	36.0	45.9	22.7
S x M																			
SN	2.7	8.4	18.1	17.9	60.1	66.2	55.6	106.8	175.8	170.0	160.7	102.7	135.5	3.4	25.4	36.9	52.5	61.4	26.4
SW	2.7	5.2	20.0	33.9	65.8	70.7	70.1	63.4	156.1	111.1	146.5	80.4	142.3	3.0	26.0	22.6	53.7	57.5	31.1
IN	1.1	6.7	11.6	25.7	13.7	21.8	13.8	35.7	45.2	59.9	46.6	27.7	39.3	1.5	14.5	21.7	19.3	30.4	14.8
IW	2.1	3.6	12.0	19.0	19.8	27.3	16.6	29.7	39.2	54.5	50.1	28.5	35.0	1.4	14.6	22.5	18.3	34.2	18.6
S x P																			
SE	2.3	8.4	20.8	19.6	66.3	75.3	78.5**	85.6	178.7	151.4	159.7	107.8	147.6	3.6	26.5	29.9	53.1	65.4	30.9
SP	3.1	5.2	17.3	32.2	59.6	61.6	47.2	84.6	153.2	129.6	147.5	75.3	130.2	2.8	24.9	29.7	53.1	53.5	26.6
IE	1.3	5.9	13.1	19.0	15.1	20.6	14.6	30.3	41.0	51.2	46.2	29.1	32.4	1.4	15.3	23.9	21.6	32.1	19.7
IP	1.8	4.4	10.6	25.7	18.4	28.5	15.8	35.1	43.4	63.2	50.5	27.1	42.0	1.5	13.8	20.2	16.0	32.5	13.6
M x P																			
NE	1.8	9.0	14.5	15.2	39.3	46.3	44.3	73.3	103.7	127.2	98.8	73.9	84.0	2.7	22.0	31.7	34.0	47.4	21.0
NP	2.0	6.1	15.2	28.4	34.5	41.8	25.1	69.2	117.3	102.6	108.5	56.4	90.8	2.2	17.9	26.9	37.8	44.4	20.2
WE	1.8	5.3	19.4	23.4	42.2	49.7	48.8	42.6	116.0	75.4	107.1	62.9	96.0	2.3	19.8	22.1	40.7	50.1	29.7
WP	2.9	3.5	12.7	29.5	43.4	48.3	37.9	50.5	79.3	90.2	89.5	46.0	81.4	2.0	20.8	23.0	31.5	41.7	20.0
SE±	0.3	2.3	3.2	8.1	7.2	9.8	5.3	16.0	17.6	19.5	26.4	16.2	24.1	0.5	5.2	7.9	8.7	11.0	5.0
CD5%	NS	NS	NS	NS	NS	NS	11.4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
System																			
S	2.7**	6.8	19.1**	25.9	63.0**	68.5**	62.9**	85.1**	166.0**	140.5**	153.6**	91.5**	138.9**	3.2**	25.7**	29.8	53.1**	59.5**	23.8 **
I	1.6	5.2	11.8	22.3	16.8	24.6	15.2	32.7	42.2	57.2	48.4	28.1	37.2	1.5	14.6	22.1	18.8	32.3	16.7
Method																			
N	1.9	7.6	14.9	21.8	36.9	44.0	34.7*	71.3*	110.5	114.9*	103.6	65.2	87.4	2.5	19.9	29.3	35.9	45.9	20.6
W	2.4	4.4	16.0	26.5	42.8	49.0	43.4	46.6	97.7	82.8	98.3	54.5	88.7	2.2	20.3	22.6	36.0	45.9	24.8
Pattern																			
E	1.8*	7.2	16.9	19.3	40.7	48.0	46.6**	58.0	109.9	101.3	103.0	68.4	90.0	2.5	20.9	26.9	37.4	48.7	25.3
[illegible]	[illegible]	4.8	13.9	29.0	39.0	45.0	31.5	59.9	98.3	96.4	99.0	51.2	96.1	2.1	19.4	25.0	34.6	43.0	20.1
[illegible]	0.2	1.6	2.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CD 5%	0.5	NS	4.9	NS	10.9	14.8	8.1	24.2	26.8	[illegible]	40.0	24.6	36.5	0.8	7.9	NS	13.1	16.7	7.6

towards maturity (87.8, 59.8 and 22.7 mg plant^{-1}) in the summer seasons during 1983 and 1984 as well as during kharif, 1983.

Planting system indicated a contrasting behaviour of groundnut sown in solid from a mixed stand with sunflower. Sole crop extracted higher amount of nitrogen within each sampling comparison althrough the growth stages in each season. Statistically significant differences were amplified at every sampling except at 30 and 45 days during summer 1984 and at 60 days during kharif 1983.

Nitrogen uptake by the stem did not follow a particular trend in response to a change in the planting method. Its accumulation in the stem due to equidistant row arrangement was more than in paired rows at all the samplings. But, at 30 days during summer 1983 and 45 days during summer 1984 the reverse was true. Nevertheless, the uptake did not differ significantly by the planting pattern at any stage except at 30 and 75 days during summer 1983.

Significant interaction was observed between planting system and pattern at 75 days during summer 1983, while none of the interactions were significant in the other seasons.

c. Pods : The uptake of nitrogen in pods increased consistently from their initiation and development (33.7, 60.2 and 53.1 mg plant^{-1}) to a mean maximum of 215.6, 289.5 and 67.6 mg plant^{-1} at 105 days during summer 1983 and at 90 days, during summer 1984 and kharif 1983 respectively. This was followed by a sharp decline at harvest (170.6, 197.1 and 54.9 mg plant^{-1}). Significant response was apparent by the different

Table 35. Nitrogen uptake (mg per plant) by pods of groundnut as influenced by different treatments

Treat-ment	Summer 75 DAS 1983	Summer 75 DAS 1984	Summer 90 DAS 1983	Summer 90 DAS 1984	Summer 105 DAS 1983	Summer 105 DAS 1984	Summer 120 DAS 1983	Kharif 75 DAS 1983	Kharif 90 DAS 1983	Kharif 105 DAS 1983
SNE	77.1	91.7	292.3	432.2	342.8	349.0	353.3	61.8	94.5	95.4
SNP	73.0	108.5	320.8	352.4	318.6	289.1	231.5	88.1	78.6	59.0
SWE	71.8	66.1	234.0	327.7	362.1	326.3	260.8	77.5	73.4	66.1
SWP	27.5	95.4	112.1	415.6	332.1	224.4	216.9	69.9	74.8	54.7
INE	7.6	44.3	54.7	221.3	85.2	111.5	94.8	18.2	57.8	45.4
INP	4.0	33.2	25.4	168.0	103.4	77.9	49.4	40.8	54.5	33.3
IWE	4.2	17.5	24.5	181.8	95.4	85.2	88.2	52.6	56.5	58.2
IWP	4.2	24.9	67.7	217.3	84.9	113.3	69.8	16.0	50.9	26.8
SE ±	12.0	12.7	57.6	22.7	48.1	33.0	42.5	21.1	14.6	13.4
CD 5%	25.7	27.2	123.7	48.7	103.2	70.8	91.2	45.3	NS	28.7
Mean	33.7	60.2	141.4	289.5	215.6	197.1	170.6	53.1	67.6	54.9
S x M										
SN	75.0	100.1	306.5*	392.3	330.7	319.1	292.4	74.9	86.5	77.2
SW	49.6	80.7	173.0	371.7	347.1	275.4	238.7	73.7	74.1	60.4
IN	5.8	38.7	40.0	194.7	94.3	94.7	72.1	29.5	56.1	39.3
IW	4.2	21.2	46.1	199.6	90.1	99.2	79.0	34.3	53.7	42.5
S x P										
SE	74.4	78.9	263.1	380.0	352.4	337.8	306.9	69.6	83.9	80.7
SP	50.2	101.9	216.4	384.0	325.3	256.7	224.2	79.0	76.7	56.8
IE	5.9	30.9	39.6	201.6	90.3	98.3	91.5	35.4	57.1	51.8
IP	4.1	29.0	46.5	192.7	94.1	95.6	59.6	28.4	52.7	30.0
M x P										
NE	42.3	68.0	173.5	326.8**	214.0	230.3	224.0	40.0*	76.1	70.4
NP	38.5	70.8	173.1	260.2	211.0	183.4	140.4	64.4	66.5	46.1
WE	38.0	41.8	129.2	254.8	228.7	205.7	174.3	65.0	64.9	62.1
WP	15.8	60.1	89.9	316.4	208.5	168.8	143.3	42.9	62.8	40.7
SE ±	8.5	9.0	40.8	16.0	34.0	23.3	30.1	14.9	10.3	9.4
CD 5%	NS	NS	87.4	34.4	NS	NS	NS	32.0	NS	NS
System										
S	62.3**	90.4**	239.8**	382.0**	338.9**	297.2**	265.5**	74.3**	80.3**	68.8**
I	5.0	29.9	43.1	197.2	92.2	96.7	75.5	31.9	54.9	40.9
Method										
N	40.4*	69.4*	173.3*	293.5	212.5	206.9	182.2	52.2	71.3	58.3
W	26.9	50.9	109.6	285.6	218.6	187.3	158.8	54.0	63.9	57.4
Pattern										
E	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
P	27.2	65.5	131.5	238.[illegible]	209.7	176.2	141.9	53.7	64.[illegible]	43.4
SE ±	6.0	6.3	28.8	[illegible]	24.0	16.5	21.3	10.5	7.[illegible]	6.7
CD 5%	12.9	13.6	61.8	34.[illegible]	51.6	35.4	45.6	22.6	15.7	14.3

treatments at periodical samplings except at 90 days during *kharif* 1983 (Table 35).

Nitrogen uptake by pods in the intercropping system was severely deterred compared to the sole crop. The greater amount of nitrogen accumulated in the pods of groundnut in monoculture was highly significant throughout the reproductive growth in each season.

Narrow rows in general tended to accumulate more nitrogen in the pods than the wider row treatments. But, this effect was significant only at 75 and 90 days during summer 1983 and at 75 days during summer 1984.

Planting groundnut in equidistant row treatments removed higher amount of nitrogen than in the paired rows althrough the samplings except at 30 days during *kharif* 1983. But, this effect was significant only at 30 days during summer 1983 and at maturity in all the three seasons.

Interactions were significant between planting system and method at 90 days during summer 1983 and between planting method and pattern at 75 days during *kharif* 1983.

4.2.2.2.2 Phosphorus

a. Leaves : Phosphorus accumulation by the leaves was markedly influenced by different treatments (Table 36). The mean uptake increased from 0.5, 1.3 and 1.8 mg plant^{-1} at 30 days during summer 1983, 1984 and *kharif* 1983 to a maximum of 11.8, 7.2 and 10.7 mg plant^{-1} at 60 days in the respective seasons. The uptake then declined steadily till maturity.

Table 36. Phosphorus uptake (mg per plant) by the leaves of groundnut as influenced by different treatments

	Summer 30		45		60		75		90		105		120	Kharif 30	45	60	75	90	105
	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984	1983	1983					
SNE	0.9	2.1	3.4	3.2	20.9	10.9	12.2	13.1	8.8	10.9	8.6	4.4	0.9	2.9	9.0	19.4	12.0	6.7	1.0
SNP	0.7	2.8	2.4	2.8	12.6	6.1	9.4	8.4	8.4	6.3	7.5	3.5	0.5	1.8	7.7	12.5	16.7	6.3	1.4
SWE	0.7	1.2	3.5	3.8	20.1	10.8	13.5	9.8	12.0	7.1	6.9	4.8	0.7	2.7	8.3	11.9	14.0	5.0	1.4
SWP	0.5	1.0	2.1	3.4	18.5	7.7	10.0	7.7	8.8	3.4	5.9	2.0	0.7	2.4	6.7	10.5	15.8	4.1	0.8
INE	0.3	0.8	1.6	1.6	6.1	6.3	2.5	3.3	3.6	3.9	2.4	1.4	0.5	1.2	6.0	7.6	6.5	3.0	0.5
INP	0.3	1.0	1.6	2.0	3.6	4.4	2.2	2.3	3.1	3.8	1.8	1.5	0.4	1.0	4.5	6.6	5.4	2.0	1.5
IWE	0.3	1.1	1.2	2.3	7.0	7.1	3.4	4.2	4.5	4.3	3.6	1.9	0.6	1.2	3.8	7.8	8.6	4.5	1.0
IWP	0.3	0.7	1.5	1.8	5.4	4.4	2.6	2.8	2.3	3.6	1.9	1.8	0.4	1.4	5.0	9.3	6.5	3.6	0.6
SE ±	0.2	0.5	0.6	1.0	5.9	2.4	3.1	1.8	1.8	2.5	1.7	1.0	0.2	0.6	2.2	4.7	2.1	1.9	0.4
CD 5%	0.4	1.0	1.4	NS	12.6	NS	6.7	3.9	3.8	NS	3.8	2.3	NS	1.3	NS	NS	4.5	NS	NS
Mean	0.5	1.3	2.2	2.6	11.8	7.2	7.0	6.4	6.4	5.4	4.8	2.7	0.6	1.8	6.4	10.7	10.7	4.4	1.0
S X M																			
SN	0.8	2.4*	2.9	3.0	16.8	8.5	10.8	10.7	8.6	8.6	8.0	3.9	0.7	2.3	8.3	15.9	14.3	6.5	1.2
SW	0.6	1.1	2.8	3.6	19.3	9.2	11.7	8.7	10.4	5.2	6.4	3.4	0.4	2.5	7.5	11.2	14.9	4.5	1.1
IN	0.3	0.9	1.6	1.8	4.8	5.3	2.3	2.8	3.3	3.8	2.1	1.4	0.7	1.1	5.2	7.1	5.9	2.4	1.0
IW	0.3	0.9	1.3	2.0	6.2	5.7	2.4	3.5	3.4	3.9	2.7	1.8	0.5	1.3	4.4	8.5	7.5	4.0	0.8
S X P																			
SE	0.8	1.6	3.4	3.5	20.5	10.8	12.8	11.4	10.4	9.0	7.7	4.6	0.8	2.8	8.6	15.6	13.0*	5.8	1.2
SP	0.6	1.9	2.2	3.1	15.6	6.9	9.7	8.0	8.6	4.8	6.7	2.7	0.5	2.1	7.2	11.5	16.2	5.2	1.1
IE	0.3	0.9	1.4	1.9	6.5	6.7	2.4	3.7	4.0	4.1	3.0	1.6	0.6	1.2	4.9	7.7	7.5	3.7	0.7
IP	0.3	0.8	1.5	1.9	4.5	4.4	2.4	2.5	2.7	3.7	1.8	1.6	0.4	1.2	4.7	7.9	5.9	2.7	1.0
M X P																			
NE	0.6	1.4	2.5	2.4	13.5	8.6	7.3	8.2	6.2	7.4	5.5	2.9	0.7	2.0	7.5	13.5	9.2	4.8	0.7*
NP	0.5	1.9	2.0	2.4	8.2	5.2	5.8	5.3	5.7	5.0	4.6	2.5	0.6	1.4	6.1	9.5	11.0	4.0	1.4
WE	0.5	1.1	2.3	3.0	13.5	8.9	7.9	7.0	8.2	5.7	5.2	3.3	0.4	1.9	6.0	9.8	11.3	4.7	1.2
WP	0.4	0.8	1.8	2.6	11.9	6.0	6.3	5.2	5.5	3.5	3.9	1.9	0.5	1.9	5.8	9.9	11.1	3.8	0.7
SE ±	0.1	0.3	0.5	0.7	4.2	1.7	2.2	1.3	1.3	1.8	1.2	0.7	0.1	0.4	1.5	3.3	1.5	1.3	0.3
CD 5%	NS	0.7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	3.2	NS	0.6
System																			
S	0.7**	1.8**	2.8**	3.3**	18.1**	8.9**	11.3**	9.7**	9.5**	6.9*	7.2*	3.7**	0.7*	2.4**	7.9*	13.6*	14.6**	5.5*	[illegible]
I	0.3	0.9	1.5	1.9	5.5	5.5	2.4	3.1	3.4	[illegible]	2.4	1.6	0.4	1.2	4.8	7.8	6.7	3.2	[illegible]
Method																			
N	0.5	1.7*	2.2	2.4	10.8	6.9	6.6	6.8	6.0	6.2	5.1	2.7	0.6	1.7	6.8	11.5	10.1	4.4	[illegible]
W	0.5	1.0	2.1	2.8	12.7	7.5	7.1	6.1	6.2	4.6	4.6	2.6	0.6	1.9	5.9	9.9	11.2	4.3	0.9
Pattern																			
E	0.6	1.3	2.4	2.7	13.5	8.8*	7.6	7.6*	7.2	[illegible]	5.4	3.1	0.7	2.0	6.8	11.7	10.3	4.8	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SE ±	0.1	0.2	0.3	0.5	2.9	1.2	1.6	[illegible]	[illegible]	[illegible]	[illegible]	0.5	0.1	[illegible]	[illegible]	[illegible]	1.0	[illegible]	[illegible]
CD 5%	0.2	0.5	0.7	1.1	6.3	2.6	3.4	1.9	[illegible]	[illegible]	1.9	1.1	0.2	[illegible]	2.3	5.0	[illegible]	2.0	[illegible]

Planting system manifested a marked variation in the amount of phosphorus removed by the leaves at different stages of crop growth. The performance of sole crop was excellent in that it extracted significantly greater amount of phosphorus at every stage except at harvest only during kharif, 1983.

The method of planting in narrow and wide row treatments did not manifest a consistent trend in the amount of phosphorus accumulated by the leaves. The equidistant row arrangement in general registered a higher uptake than the paired rows. But, the differences were significant only at 60 and 75 days of crop growth during summer 1984.

Planting system and method indicated a significant interaction at 30 days during summer, 1984, while planting system interacted with planting pattern at 75 days and the latter with planting method at 105 days in the kharif season. Higher order interactions were not apparent in any season.

b. Stem : The mean uptake of phosphorus by the stem of groundnut increased from 0.3, 0.5 and 0.7 mg plant^{-1} at 30 days during summer 1983, 1984 and kharif 1983 to a maximum of 5.1, 4.4 and 10.4 mg plant^{-1} at 75 days in the respective seasons. The uptake then declined to 2.0, 1.0 and 1.9 mg plant^{-1} at harvest (Table 37).

Groundnut interplanted between the rows of sunflower experienced a great reduction in the amount of phosphorus removed althrough the growth stages. The sole crop accumulated significantly greater amount of phosphorus in the stem at every stage

Table [illegible]. Phosphorus uptake (mg per plant) by the stem of groundnut as influenced by different treatments

Treat-ment	Summer 30 DAS 1983	Summer 30 DAS 1984	Summer 45 DAS 1983	Summer 45 DAS 1984	Summer 60 DAS 1983	Summer 60 DAS 1984	Summer 75 DAS 1983	Summer 75 DAS 1984	Summer 90 DAS 1983	Summer 90 DAS 1984	Summer 105 DAS 1983	Summer 105 DAS 1984	Summer 120 DAS 1983	Kharif 1983 30 DAS	Kharif 1983 45 DAS	Kharif 1983 60 DAS	Kharif 1983 75 DAS	Kharif 1983 90 DAS	Kharif 1983 105 DAS
SNE	0.31	0.99	1.6	1.3	12.5	6.2	9.5	7.8	6.3	2.9	4.5	2.3	2.7	1.1	4.5	13.1	12.7	4.2	1.9
SNP	0.34	0.41	2.2	1.4	9.5	4.5	6.6	6.9	8.7	2.5	6.9	1.3	4.1	0.9	3.4	13.5	16.0	3.0	2.4
SWE	0.30	0.42	2.0	1.5	13.3	5.7	9.5	4.9	8.4	2.4	5.6	1.4	3.4	1.0	3.9	8.2	16.6	2.9	2.4
SWP	0.46	0.48	1.3	2.5	11.0	4.4	6.3	3.9	5.0	2.5	4.1	1.0	2.8	0.8	3.2	7.6	11.8	3.2	2.3
INE	0.13	0.45	0.5	1.1	1.9	2.5	2.2	2.8	2.2	1.9	1.4	0.4	1.0	0.5	2.5	8.7	7.3	2.1	1.5
INP	0.14	0.66	0.6	1.1	3.1	3.0	1.8	2.9	2.6	2.4	1.3	0.6	0.7	0.4	1.7	6.9	6.1	2.0	1.5
IWE	0.20	0.46	0.5	1.5	3.5	2.8	1.8	3.1	1.9	1.7	1.2	0.8	0.9	0.4	2.0	7.7	7.2	2.6	2.2
IWP	0.31	0.44	0.8	1.3	4.8	3.7	2.9	3.3	2.6	2.2	1.7	0.5	0.7	0.5	2.1	8.1	5.5	1.7	1.4
SE±	0.07	0.16	0.4	0.4	1.3	1.6	1.3	1.0	1.5	0.6	0.9	0.3	0.5	0.3	0.7	2.6	2.6	0.8	0.5
CD5%	0.15	0.35	0.8	NS	2.0	NS	2.9	2.1	3.2	NS	1.9	0.7	1.0	NS	1.6	NS	5.6	NS	NS
Mean	0.27	0.54	1.2	1.5	4.4	4.1	5.1	4.4	4.7	2.3	3.3	1.0	2.0	0.7	2.9	9.2	10.4	2.7	1.9
S x M																			
SN	0.32	0.70	1.9	1.3	11.0	5.3	8.0	7.3**	7.5	2.7	5.7	1.8*	3.4	1.0	3.9	13.3	14.5	3.6	2.1
SW	0.38	0.40	1.6	2.0	12.1	3.4	7.9	4.4	6.7	2.4	4.8	1.2	3.1	0.9	3.5	7.9	14.2	3.0	2.3
IN	0.13	0.55	0.5	1.1	2.5	2.7	2.0	2.8	2.4	2.1	1.3	0.5	0.8	0.4	2.1	7.8	6.7	2.0	1.5
IW	0.25	0.45	0.6	1.4	4.1	3.2	2.3	3.2	2.2	1.9	1.4	0.6	0.8	0.4	2.0	7.9	6.3	2.1	1.8
S x P																			
SE	0.30	0.70*	1.8	1.4	12.9	4.3	9.5*	6.3	7.3	2.6	5.0	1.8	3.0	1.0	4.2	10.6	14.6	3.5	2.1
SP	0.40	0.39	1.7	1.9	10.2	4.4	6.4	5.4	6.8	2.5	5.5	1.1	3.4	0.8	3.3	10.5	13.9	3.1	2.3
IE	0.16	0.45	0.5	1.3	2.7	2.6	2.0	2.9	2.0	1.8	1.3	0.6	0.9	0.4	2.2	8.2	7.2	2.3	1.8
IP	0.22	0.55	0.7	1.2	3.9	3.3	2.3	3.1	2.6	2.3	1.5	0.5	0.7	0.4	1.9	7.5	5.8	1.8	1.4
M x P																			
NE	0.22	0.72	1.0	1.2	7.2	4.3	5.8	5.3	4.2	2.4	2.9	1.3	1.8	0.8	3.5	10.9	10.0	3.1	1.7
NP	0.24	0.53	1.4	1.2	6.3	3.7	4.2	4.9	5.6	2.4	4.1	0.9	2.4	0.6	2.5	10.2	11.0	2.5	1.9
WE	0.25	0.44	1.2	1.5	8.4	2.6	5.6	4.0	5.1	2.0	3.4	1.1	2.1	0.7	2.9	7.9	11.9	2.7	2.3
WP	0.38	0.41	1.0	1.9	7.9	4.0	4.6	3.6	3.8	2.3	2.9	0.7	1.7	0.6	2.6	7.8	8.6	2.4	1.8
SE±	0.05	0.11	0.3	0.3	1.4	1.1	0.9	0.7	0.5	0.4	0.1	0.2	0.3	0.2	0.5	1.8	1.8	0.6	0.4
CD5%	NS	0.25	NS	NS	NS	NS	2.0	1.5	NS	NS	NS	0.5	NS	NS	NS	NS	NS	NS	NS
System																			
S	0.35**	0.55	1.8**	1.7*	11.6**	4.4	8.0**	5.9**	7.1**	2.6	5.3**	1.5**	3.2**	0.9**	3.7**	10.6	14.3**	3.3**	2.2*
I	0.19	0.50	0.6	1.2	3.3	3.0	2.2	3.0	2.3	2.0	1.4	0.6	0.8	0.4	2.1	7.8	6.5	2.1	1.6
Method																			
N	0.23*	0.62*	1.2	1.2*	6.7	4.0	5.0	5.1*	4.9	2.4	3.5	1.1	2.1	0.7	3.0	10.5	10.5	2.8	1.8
W	0.31	0.42	1.1	1.7	8.1	3.3	5.1	3.8	4.5	2.2	3.1	0.9	1.9	0.7	2.8	7.9	10.3	2.6	2.1
Pattern																			
E	0.23	0.58	1.1	1.3	7.8	3.5	5.7	4.6	4.7	2.2	3.2	1.2**	2.0	0.7	3.2	9.4	10.9	2.9	2.0
P	0.31	0.47	1.2	1.6	7.1	3.9	4.4	4.2	4.7	2.4	3.5	0.8	2.1	0.6	2.6	9.0	9.8	2.5	1.9
SE±	0.03	0.08	0.2	0.2	1.0	0.8	0.7	0.5	0.7	0.3	0.4	0.1	0.2	0.1	0.4	1.3	1.3	0.4	0.3
CD5%	0.07	0.17	0.4	0.4	2.2	NS	1.4	1.1	1.6	NS	0.9	0.3	0.5	0.3	0.8	NS	2.8	0.8	0.6

during summer 1983 and at 45, 75 and 105 days during summer 1984. Its accumulation in the stem of sole crop during *kharif* 1983 similarly exceeded the intercrop although the treatment effects were statistically equivocal only at 60 days.

Response to the changed row width on phosphorus uptake at different stages of crop growth was not consistent though the differences were significant at 30 days during summer 1983 and at 30, 45 and 75 days during summer 1984. In *kharif* though the uptake in general was more with narrow row treatment it was on par with the wider row treatment.

Planting pattern in the like manner had no striking influence on the uptake and did not indicate a systematic trend in the summer seasons. In *kharif* the equidistant row arrangement registered marginally higher uptake throughout the crop growth.

Planting system showed a significant interaction with planting method at 75 and 105 days during summer 1984 while with planting method at 75 days during summer 1983 and at 30 days during summer 1984.

c. **Pods** : The mean uptake of phosphorus by groundnut pods increased from 2.9 and 2.6 mg plant^{-1} during summer 1983 and 1984 to a maximum of 5.3 mg plant^{-1} at 105 days and 5.9 mg plant^{-1} at 90 days during the corresponding years. In *kharif*, the uptake was maximum (7.7 mg plant^{-1}) at 75 days and declined to 2.9 and 2.8 mg plant^{-1} at 90 and 105 days respectively (Table 38).

Planting system had a marked influence on the uptake of phosphorus in the three seasons. The amount of phosphorus

Table 38. Phosphorus uptake (mg per plant) by pods of groundnut as influenced by different treatments

Treatment	Days after sowing – Summer 75 (1983)	75 (1984)	90 (1983)	90 (1984)	105 (1983)	105 (1984)	120 (1983)	Kharif 1983 – 75	90	105
SNE	6.2	3.2	7.9	6.3	10.6	7.1	9.1	4.8	4.4	4.4
SNP	5.4	4.5	9.5	8.0	8.1	8.4	4.0	11.5	4.1	3.2
SWE	7.2	3.3	7.0	7.4	10.4	9.1	5.7	11.4	3.2	2.9
SWP	2.6	3.8	2.9	9.0	7.4	5.8	4.7	9.6	2.8	2.7
INE	0.7	2.1	1.0	4.2	1.4	3.0	1.7	2.5	2.4	3.0
INP	0.3	1.6	0.6	3.9	1.5	2.2	0.9	5.4	2.0	1.6
IWE	0.3	1.0	0.4	4.2	1.9	2.3	1.5	7.2	2.2	3.5
IWP	0.3	1.0	1.5	4.4	1.3	2.6	1.8	2.5	1.8	1.5
SE ±	1.0	1.0	0.9	1.8	1.2	1.5	1.4	2.8	0.8	0.7
CD 5%	2.1	2.3	1.9	NS	2.6	3.2	3.0	5.9	1.6	1.5
Mean	2.9	2.6	3.8	5.9	5.3	5.1	3.7	7.7	2.9	2.8
S x M										
SN	5.8	3.8	8.7*	7.1	9.3	7.7	6.5	11.6	4.2	3.8
SW	4.9	2.9	4.9	8.2	8.9	7.4	5.2	10.5	3.0	2.8
IN	0.5	1.8	0.8	4.0	1.4	2.6	1.3	3.9	2.2	2.3
IW	0.3	1.0	0.9	4.3	1.6	2.4	1.6	4.8	2.0	2.5
S x P										
SE	6.7*	2.6	7.4	6.8	10.5	8.1	7.4	10.6	3.8	3.6
SP	4.0	4.1	6.2	8.5	7.7	7.1	4.3	11.5	3.4	2.9
IE	0.5	1.5	0.7	4.2	1.6	2.6	1.6	4.8	2.3	3.2
IP	0.3	1.3	1.0	4.1	1.4	2.4	1.3	3.9	1.9	1.5
M x P										
NE	3.4	2.6	4.4*	5.2	6.0	5.0	5.4	6.1*	3.4	3.7
NP	2.8	3.0	5.0	5.9	4.8	5.3	2.4	9.4	3.0	2.4
WE	3.7	1.5	3.7	5.8	6.1	5.7	3.6	9.3	2.7	3.2
WP	1.4	2.4	2.2	6.7	4.3	4.2	2.2	6.0	2.3	2.1
SE ±	0.7	0.7	0.6	1.3	0.8	1.1	1.0	2.0	0.5	0.5
CD 5%	1.5	NS	1.4	NS	NS	NS	NS	4.2	NS	NS
System										
S	5.3**	3.4**	6.8**	7.7**	9.1**	7.6**	5.9**	11.1**	3.6*	3.3*
I	0.4	1.4	0.9	4.2	1.5	2.5	1.5	4.4	2.1	2.4
Method										
N	3.1	2.8	4.7**	5.6	5.4	5.2	3.9	7.8	3.2	3.0*
W	2.6	2.0	2.9	6.2	5.2	4.9	3.4	7.7	2.5	2.6
Pattern										
E	3.6*	2.1	4.1	5.5	6.1*	5.4	4.5*	7.7	3.0	3.4**
P	2.1	2.7	3.6	6.3	4.6	4.7	2.8	7.7	2.7	2.2
SE ±	0.5	0.5	0.4	0.9	0.6	0.7	0.7	1.4	0.4	0.3
CD 5%	1.1	1.1	1.0	1.9	1.3	1.6	1.5	3.0	0.8	0.8

removed by the pods in monoculture was highly significant than in the intercrop system at all the stages in the summer seasons. Similarly, in kharif the sole crop was significantly superior to the intercropped groundnut.

Narrow row treatment in general tended to accumulate more phosphorus than the wider rows. But, this effect was not significant at any stage except at 90 days during summer 1983.

Equidistant rows in general had an edge over the paired row pattern. But, the uptake between the two treatments could not be discriminated significantly different except at 30, 105 and 120 days during summer 1983 and at harvest during kharif, 1983.

The interactions between planting system and method were significant at 90 days, while, between planting system and pattern at 75 days during summer 1983. Interaction between planting method and pattern was recorded at 90 days during summer 1983 and at 75 days during kharif, 1983. The second order interactions were not significant.

4.2.2.2.3 Potassium

a. **Leaves** : The mean uptake of potassium by the leaves was enhanced from 8.1, 10.0 and 9.8 mg plant^{-1} at 30 days to a maximum of 92.5, 69.5 and 57.6 mg plant^{-1} at 75 days during summer, 1983, 1984 and kharif 1983 respectively. The mean uptake correspondingly declined to 14.9, 22.2 and 3.7 mg plant^{-1} at harvest (Table 39).

Accumulation of potassium in the leaves of groundnut was largely influenced by the planting system. The leaves in a pure stand of groundnut by far exceeded the uptake of potassium in intercropping system throughout the crop growth in each season. Despite, its outperformance at every stage, the monoculture was not significantly superior to the intercrop at maturity during summer 1983 and kharif 1983.

Planting method had no pronounced influence. The uptake of potassium in narrow and wider row treatments could not be detected statistically dissimilar at any stage except at 45 days during summer 1983 and at 30 days during summer 1984.

Accumulation of potassium in the paired row pattern in general was less than in the uniform row treatments. Nevertheless, both the treatments were on par except at 45, 60 and 75 days during summer 1983 and at 60, 75 and 90 days during summer 1984.

Interaction between planting system and method was significant at 45 and 60 days during summer 1983, at 30 and 75 days during summer 1984 and at 90 days during kharif, 1983. Planting system and pattern revealed a significant interaction at 75 days during summer 1983, at 30 and 75 days during summer 1984 and at 75 days during kharif 1983. The interaction between planting method and pattern was significant at 90 days during summer, 1983.

Table [illegible]. Potassium uptake (mg per plant) by the leaves of groundnut as influenced by different treatments

Treat - ment	Days after sowing																		
	30		45		60		75		90		105		120	30	45	60	75	90	105
	Summer													Kharif					
	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984	1983	1983					
SNE	12.7	22.9	17.6	12.3	123.8	97.0	173.9	146.1	80.2	64.2	91.4	30.3	16.6	13.2	17.3	53.8	61.1	26.8	3.6
SNP	10.0	10.0	15.1	12.1	76.9	63.5	102.9	96.3	122.4	39.7	73.5	25.8	16.7	9.0	15.4	39.2	86.9	28.0	4.9
SWE	10.5	8.6	10.8	12.7	74.0	83.8	197.1	112.5	126.0	43.6	85.0	39.2	16.6	13.1	15.9	32.4	72.0	19.7	4.6
SWP	9.6	7.8	7.3	13.0	76.8	47.5	106.6	70.0	58.1	22.6	73.4	16.7	14.7	11.9	13.1	32.1	81.6	18.2	3.7
INE	5.2	5.5	7.1	6.8	28.0	42.3	37.3	33.7	37.3	33.1	30.8	14.3	13.1	7.9	9.8	17.5	40.2	11.8	2.0
INP	5.3	9.8	7.4	6.5	18.4	31.0	28.3	21.4	44.1	27.8	31.9	14.2	13.4	6.6	7.3	16.4	36.3	9.5	5.1
IWE	6.0	7.7	7.3	8.7	35.8	48.5	51.8	40.6	43.1	37.1	50.1	17.6	14.4	7.9	7.2	17.1	48.5	20.0	3.5
IWP	5.8	7.9	4.8	7.1	27.8	29.7	42.7	35.1	27.7	23.6	38.5	19.3	13.4	8.7	9.3	19.4	34.0	14.6	2.6
SE±	1.6	3.2	1.5	4.3	12.5	12.2	12.5	15.3	25.9	10.0	14.3	6.7	4.4	2.3	4.2	8.7	9.4	5.6	1.6
CD5%	3.3	6.9	3.3	NS	26.9	26.2	26.9	32.9	55.5	21.4	30.8	14.4	NS	NS	NS	18.6	20.1	11.9	NS
Mean	8.1	10.0	9.7	9.9	57.7	55.4	92.5	69.5	67.4	36.5	59.3	22.2	14.9	9.8	11.9	28.5	57.6	18.6	3.7
S x M																			
SN	11.3	16.4*	16.3**	12.2	100.3*	80.2	138.3	121.2*	101.3	51.9	82.4	28.0	19.3	11.1	16.3	46.5	74.0	27.4*	4.2
SW	10.0	8.2	9.0	15.6	75.4	65.6	151.8	91.2	92.0	33.1	79.2	27.9	15.6	12.5	14.5	32.2	76.8	18.9	4.1
IN	5.2	7.6	7.2	6.6	23.2	36.6	32.8	27.5	40.7	30.4	31.3	14.2	13.2	7.2	8.5	16.9	38.2	10.8	3.9
IW	5.9	7.8	6.0	7.9	31.8	39.1	47.2	37.8	35.4	30.3	44.3	18.4	13.9	8.3	8.2	18.2	41.2	17.3	3.0
S x P																			
SE	11.6	15.7*	14.2	12.5	98.9	90.4	185.4**	129.3*	103.1	53.9	88.2	34.7	16.6	13.1	16.6	43.1	66.5*	23.2	4.1
SP	9.8	8.9	11.2	15.3	76.8	55.5	104.7	83.1	90.2	31.1	73.4	21.2	18.3	10.4	14.2	35.6	84.2	23.1	4.3
IE	5.6	6.6	7.2	7.7	31.9	45.4	44.5	37.1	40.2	35.1	40.4	15.9	13.7	7.9	8.5	17.3	44.3	16.1	2.7
IP	5.5	6.8	6.1	6.8	23.1	30.3	35.5	28.2	35.9	25.7	35.2	16.7	13.4	7.6	8.3	17.9	35.1	12.0	4.2
M x P																			
NE	8.9	14.2	12.3	9.5	75.9	69.6	105.5	89.9	58.7*	48.6	61.1	22.3	14.8	10.5	13.5	35.6	50.6	19.5	2.8
NP	7.6	9.9	11.2	9.3	47.6	47.2	65.6	58.8	83.2	33.7	52.7	20.0	17.7	7.8	11.3	27.8	61.6	18.7	5.4
WE	8.2	6.1	9.0	10.7	54.9	66.1	124.4	76.5	84.5	40.3	67.5	28.4	15.5	10.5	11.5	24.7	60.2	19.8	4.0
WP	7.7	7.8	6.0	12.8	52.3	38.6	74.6	52.5	42.9	23.1	55.9	18.0	14.0	10.3	11.2	25.7	57.8	16.4	3.1
SE±	1.1	2.3	1.1	3.0	8.9	8.6	12.2	10.8	18.3	7.1	10.1	4.7	3.1	1.6	3.0	6.1	6.6	3.9	1.1
CD5%	NS	4.9	2.3	NS	19.0	NS	26.2	23.3	39.2	NS	NS	NS	NS	NS	NS	NS	14.2	8.4	NS
System																			
S	10.7**	123*	12.7**	13.9*	87.9**	72.9**	145.1**	106.2**	96.7**	42.5*	80.8**	28.0*	17.5	11.8**	15.4**	39.4**	75.4**	23.2**	4.2
I	5.6	7.7	6.6	7.3	27.5	37.9	40.0	32.7	38.0	30.4	37.8	16.3	13.6	7.8	8.4	17.6	39.7	14.1	3.5
Method																			
N	8.3	12.0*	11.8**	9.4	61.8	58.4	85.5	74.4	71.0	41.2	56.9	21.1	16.3	9.2	12.4	31.7	56.1	19.1	4.1
W	8.0	8.0	7.5	11.8	53.6	52.4	99.5	64.5	63.7	31.7	61.7	23.2	14.8	10.4	11.4	25.2	59.0	18.1	3.6
Pattern																			
E	8.6	11.2	10.7*	10.1	65.4*	67.9**	115.0**	83.2**	71.6	44.5**	64.3	25.3	15.2	10.5	12.5	30.2	55.4	19.7	3.4
P	7.7	8.9	8.6	11.1	50.0	42.9	70.1	55.7	63.1	28.4	54.3	19.0	15.9	9.0	11.3	26.8	59.7	17.6	4.3
SE±	0.8	1.6	0.8	2.1	6.3	6.1	8.6	7.7	12.9	5.0	7.2	3.3	2.2	1.1	2.1	4.3	4.7	2.8	0.8
CD5%	1.7	3.4	1.6	4.6	13.4	13.1	18.5	16.5	27.7	10.7	15.4	7.2	NS	2.5	4.5	9.3	10.1	6.0	NS

b. **Stem:** The course of potassium accumulation in the stem as could be seen from the mean uptake followed an increase with the crop growth till the maximum was recorded at 75 days and then declined prior to maturity (Table 40).

Accumulation of potassium in the stem was highly influenced by the planting system. Sole crop registered relatively higher accumulation in the stem than the intercropped groundnut. The discernible effect of intercropping was significant althrough the crop growth period except at 30 days during summer 1983 and at 30 as well as 45 days during summer 1984. In kharif, the sole crop was significantly superior to the intercrop at every stage of sampling.

The row width comparisons were not statistically significant, at any stage except at 60 days during kharif, 1983. Similarly, the planting pattern revealed a significant response of the equidistant row treatments only at 75 days during summer 1983 and at 105 days during summer 1984.

The interactions were significant due to planting system and method at 75 days during summer, 1984 and at 60 days during kharif, 1983. Planting system interacted with planting pattern at 75 days during summer 1983 and at 60 and 105 days during summer 1984. The interaction between planting method and pattern was significant at 60 and 75 days during summer, 1984. The second order interactions were not significant at any stage.

Table 40. Potassium uptake (mg per plant) by the stem of groundnut as influenced by different treatments

Treat-ment	Summer 30 DAS 1983	Summer 30 DAS 1984	Summer 45 DAS 1983	Summer 45 DAS 1984	Summer 60 DAS 1983	Summer 60 DAS 1984	Summer 75 DAS 1983	Summer 75 DAS 1984	Summer 90 DAS 1983	Summer 90 DAS 1984	Summer 105 DAS 1983	Summer 105 DAS 1984	Summer 120 DAS 1983	Kharif 1983 30 DAS	Kharif 1983 45 DAS	Kharif 1983 60 DAS	Kharif 1983 75 DAS	Kharif 1983 90 DAS	Kharif 1983 105 DAS
SNE	4.0	5.1	4.2	5.5	79.8	47.7	102.7	87.8	50.8	41.8	46.0	22.2	50.1	7.3	13.3	48.9	72.1	47.7	17.6
SNP	6.7	4.6	6.6	5.8	71.5	35.7	73.1	75.0	52.9	37.3	54.3	17.0	56.6	5.7	10.9	51.2	94.2	36.7	18.3
SWE	5.3	4.2	5.5	6.5	75.5	41.7	92.5	54.0	70.8	29.5	52.6	23.4	43.5	5.9	11.9	30.2	100.0	43.5	24.1
SWP	5.9	4.6	4.1	10.1	71.1	35.5	64.3	71.5	39.5	22.2	40.2	14.2	41.4	5.1	9.0	32.2	73.4	37.7	16.8
INE	2.4	5.8	3.2	6.5	17.9	26.9	29.0	41.7	23.2	25.7	20.4	6.6	17.1	3.5	7.7	31.0	46.8	16.9	9.6
INP	2.7	6.6	3.4	4.5	19.5	24.0	24.2	34.0	26.5	17.9	20.9	9.2	19.4	3.4	6.4	24.2	39.2	19.4	9.2
IWE	5.2	4.9	2.8	6.5	27.6	24.2	28.1	42.2	19.5	19.8	19.0	9.4	19.4	3.9	7.3	27.8	47.6	25.4	12.4
IWP	5.1	4.6	2.8	6.2	30.5	43.6	34.7	42.2	22.2	22.9	20.1	8.1	16.7	4.1	7.0	31.2	33.7	18.7	10.4
SE±	1.8	1.6	0.8	1.6	8.8	6.4	10.4	8.1	9.3	6.9	8.2	2.1	11.0	1.6	2.0	7.6	16.4	8.2	5.0
CD5%	NS	NS	1.7	NS	18.8	13.6	22.2	17.3	19.9	14.8	17.6	4.6	23.5	NS	4.2	16.2	35.2	17.5	NS
Mean	4.7	5.0	4.1	6.4	49.2	34.9	56.1	56.0	38.2	27.1	34.4	13.8	33.0	4.9	9.2	34.6	63.4	30.7	14.8
S x M																			
SN	5.3	4.8	5.4	5.6	75.6	41.7	87.9	81.4*	51.8	39.5	51.1	19.6	53.3	6.5	12.1	50.0*	83.1	42.2	17.9
SW	5.6	4.4	4.8	8.3	73.3	38.6	78.4	62.7	55.1	25.8	46.4	18.8	42.4	5.5	10.4	31.2	86.7	40.6	20.4
IN	2.5	6.2	3.3	5.5	18.7	25.4	26.6	37.8	24.8	21.8	20.6	7.9	18.2	3.4	7.0	29.3	43.0	18.1	9.4
IW	5.1	4.7	2.8	6.3	29.0	33.9	31.4	42.2	20.8	21.3	19.5	8.7	18.0	4.0	7.1	29.5	40.6	22.0	11.4
S x P																			
SE	4.6	4.6	4.8	6.0	77.6	44.7*	97.6*	70.9	60.8	35.6	50.3	22.8**	46.8	6.6	12.6	39.5	86.0	45.6	20.8
SP	6.3	4.6	5.3	7.9	71.3	35.6	68.7	73.2	46.2	29.7	47.2	15.6	48.9	5.4	9.9	41.7	83.8	37.2	17.5
IE	3.8	5.3	3.0	6.5	22.7	25.5	28.5	41.9	21.3	22.7	19.7	8.0	18.2	3.7	7.6	29.4	47.2	21.1	11.0
IP	3.9	5.6	3.1	5.3	25.0	33.8	29.4	38.1	24.3	20.4	20.5	8.6	18.0	3.7	6.7	29.4	36.4	19.0	9.8
M x P																			
NE	3.2	5.4	3.7	6.0	48.8	37.3*	65.8	64.7*	37.0	33.7	34.2	14.4	33.6	5.4	10.5	39.9	59.4	32.3	13.6
NP	4.7	5.6	5.0	5.1	45.5	29.8	48.6	54.5	39.7	27.6	37.6	13.1	37.9	4.5	8.6	39.4	66.7	28.0	13.7
WE	5.2	4.5	4.1	6.5	51.5	32.9	60.3	46.1	45.1	24.6	35.8	16.4	31.4	4.9	9.6	29.0	73.8	34.4	18.2
WP	5.5	4.6	3.4	8.1	50.8	39.5	49.5	56.8	30.8	22.5	30.1	11.1	29.0	4.6	8.0	31.7	53.5	28.2	13.6
SE±	1.3	1.1	1.1	1.1	6.2	4.5	7.3	5.7	6.6	4.9	5.8	1.5	5.5	1.1	1.4	5.3	11.6	5.8	3.6
CD5%	NS	NS	NS	NS	NS	9.6	15.7	12.2	NS	NS	NS	3.2	NS	NS	NS	11.5	NS	NS	NS
System																			
S	5.5	4.6	5.1*	7.0	74.5**	40.1**	83.1**	72.1**	53.5**	32.7**	48.8**	19.2**	47.9**	6.0**	11.3**	40.6*	84.9**	41.4**	19.2**
I	3.8	5.5	3.0	5.9	23.9	29.7	29.0	40.0	22.8	21.6	20.1	8.3	18.1	3.7	7.1	29.4	41.8	20.1	10.4
Method																			
N	3.9	5.5	4.3	5.6	47.2	33.6	57.2	59.6	38.3	30.7	35.9	13.7	35.8	5.0	9.6	39.6*	63.1	30.2	13.7
W	5.4	4.6	3.8	7.3	51.2	36.2	54.9	52.5	38.0	23.6	33.0	13.8	30.2	4.7	8.8	30.3	63.7	31.3	15.9
Pattern																			
E	4.2	5.0	3.9	6.2	50.2	35.1	63.1*	56.4	41.1	29.2	35.0	15.4**	32.5	5.1	10.0	34.5	66.6	33.4	15.9
P	5.1	5.1	4.2	6.6	48.1	34.7	49.1	55.7	35.3	25.1	33.9	12.1	33.5	4.6	8.3	35.5	60.1	28.1	13.7
SE±	0.9	0.8	0.8	0.8	4.4	3.2	5.2	4.0	4.6	3.4	4.1	1.1	5.5	0.8	1.0	3.8	8.2	4.1	2.5
CD5%	NS	NS	1.7	NS	9.4	6.8	11.1	8.7	1.0	7.4	8.8	2.3	11.8	1.7	2.1	8.1	17.6	8.8	5.4

c. **Pods:** Potassium accumulated progressively in greater amounts with the commencement and development of pods at 75 days (26.8 and 26.8 mg plant^{-1}) till maturity (65.1 and 46.0 mg plant^{-1}) in the summer seasons. But, in kharif the mean uptake declined from 29.9 mg plant^{-1} at 75 days to 20.9 mg plant^{-1} at maturity (Table 41).

Groundnut intercropped between the rows of sunflower was severely affected resulting in a drastically lesser amount of potassium being removed. The accumulation of potassium in sole crop was highly significant at every stage of sampling in all the seasons.

Response to row width treatments was not strikingly different. Narrow row treatments in general performed better than the wider rows though this effect was not statistically significant in most instances except at 75 days in the summer season during both the years and at 90 days only during summer, 1984.

Planting pattern showed that the equidistant row treatments in general performed better than the paired rows and were significantly superior at 75 and 120 days during summer 1983 while, at harvest during summer 1984 and kharif, 1983.

Planting system interacted with the method of planting at 75, 90 and 120 days during summer 1983 and at 105 days during summer 1984. The interaction between planting system and pattern was found significant at 75 days during summer 1983 and at

Table [illegible] Potassium uptake (mg per plant) [illegible] as influenced by different treatments

Treat-ment	Days after sowing: 75 (Summer) 1983	75 (Summer) 1984	90 (Summer) 1983	90 (Summer) 1984	105 (Summer) 1983	105 (Summer) 1984	120 (Summer) 1983	75 (Kharif) 1983	90 (Kharif) 1983	105 (Kharif) 1983
SNE	65.3	39.3	50.4	52.8	87.9	73.5	124.2	35.7	29.7	35.9
SNP	48.3	51.1	69.5	43.6	87.3	64.5	84.8	49.6	24.2	21.5
SWE	61.7	28.8	49.4	[illegible]	96.7	66.0	85.7	45.0	22.7	25.5
SWP	20.3	36.1	21.7	40.6	77.3	43.3	71.4	37.3	[illegible]	20.4
INE	7.6	21.9	12.4	26.8	22.5	28.9	34.4	9.5	14.3	18.5
INP	3.6	17.1	7.9	20.3	25.8	24.7	27.3	20.9	13.5	12.9
IWE	3.2	8.4	6.4	17.0	30.1	34.6	53.1	32.1	13.9	22.1
IWP	4.1	11.4	17.4	22.4	23.7	32.6	40.0	9.2	13.5	10.3
SE ±	6.2	7.1	6.9	6.3	10.4	5.8	9.9	5.0	3.9	6.4
CD 5%	13.4	15.3	14.8	13.5	22.4	12.4	21.3	10.7	8.4	13.7
Mean	26.8	26.8	29.4	31.6	56.4	46.0	65.1	29.9	19.2	20.9
S x M										
SN	56.8*	45.2	59.9**	48.2	87.6	69.0**	104.5**	42.6	26.9	28.7
SW	41.0	32.4	35.5	40.7	87.0	54.6	78.5	41.1	26.4	23.0
IN	5.6	19.5	10.1	23.5	24.1	26.8	30.8	15.1	16.7	15.7
IW	3.6	9.9	11.9	19.7	26.9	33.6	46.5	20.6	13.7	16.2
S x P										
SE	63.5**	34.0	49.9	46.6	92.3	69.7*	104.9	40.3	26.2	30.7
SP	34.3	43.6	45.6	42.2	82.3	53.9	78.1	43.4	23.1	21.0
IE	5.4	15.1	9.4	21.9	26.3	31.7	43.7	20.7	14.1	20.3
IP	3.8	14.2	12.6	21.3	24.7	28.6	33.6	15.0	16.3	11.6
M x P										
NE	36.4	30.6	31.4*	39.8	55.2	51.2	79.3	22.5*	22.0	27.2
NP	25.9	34.1	38.7	31.9	56.5	44.6	56.0	35.2	21.7	17.2
WE	32.4	18.6	27.9	28.7	63.4	50.3	69.4	38.5	18.3	23.8
WP	12.2	23.7	19.5	31.6	50.5	37.9	55.7	23.2	17.8	15.4
SE ±	4.4	5.1	4.9	4.5	7.4	4.1	7.0	3.5	2.8	4.5
CD 5%	9.5	NS	10.5	NS	NS	8.8	15.1	7.5	NS	NS
System										
S	48.9**	38.8**	47.7**	44.4**	87.3**	61.8**	91.5**	41.9**	24.7**	25.8**
I	4.6	14.7	11.0	21.6	25.5	30.2	38.7	17.9	15.2	15.9
Method										
N	31.2*	32.3*	35.0**	35.9	55.9	47.9	67.7	28.9	21.8	22.2
W	22.3	21.2	23.7	30.2	56.9	44.1	62.5	30.9	18.0	19.6
Pattern										
E	34.4**	24.6	29.6	34.3	59.3	50.7**	74.3**	30.5	20.1	25.5*
P	19.1	28.9	29.1	31.8	53.5	41.3	55.9	29.2	19.7	16.3
SE ±	3.1	3.6	3.4	3.1	5.2	2.9	5.0	2.5	1.9	3.2
CD 5%	6.7	7.7	7.4	6.8	11.2	6.2	10.7	5.3	4.2	6.8

105 days during summer 1984. The interactions were significant due to planting method and pattern at 90 days during summer 1983 and 75 days during *kharif* 1983.

4.3 INTERCROPPING

Findings related to the total productivity of seed and oil, the economic returns, land use efficiency and the calorific equivalent of intercropping system compared to the sole crops are presented in this section.

4.3.1 Total seed yield (kg ha^{-1})

Comparative production potential of sunflower and groundnut components sown individually as sole crops as well as their total productivity in an associated growth under varying crop geometry are presented in Table 42. The treatment effects were highly significant in influencing the yield potential of each crop component and their overall performance in intercrop system.

Planting system indicated that the combined yield of sunflower and groundnut in intercrop system exceeded the yield from individual components sown as pure crops. The total yield (2161.90 kg ha^{-1}) during summer, 1983 was significantly superior to the sole crop yield of sunflower (1389.79 kg ha^{-1}) but was on a par with the sole crop yield of groundnut (2018.93 kg ha^{-1}). However, the combined yield from intercrop system during summer, 1984 (2702.96 kg ha^{-1}) and *kharif* 1983 (1204.42 kg ha^{-1}) showed a highly significant increase over the yields of sunflower (1465.89 and 940.55 kg ha^{-1}) or groundnut (2380.09

Table 42. Seed/oil yield (kg ha^{-1}) of sunflower and groundnut from sole and intercrop system as influenced by varying crop geometry

Treatment	Seed yield kg ha^{-1}			Oil yield kg ha^{-1}		
	Summer		Kharif	Summer		Kharif
	1983	1984	1983	1983	1984	1983
SSNE	1504.72	1682.13	919.07	561.09	620.80	354.46
SSNP	1303.81	1523.96	930.83	483.72	580.47	363.06
SSWE	1503.75	1327.07	971.17	576.40	508.07	379.38
SSWP	1246.86	1330.40	941.00	436.54	517.23	358.60
GSNE	2449.44	3027.28	776.64	836.87	994.04	219.94
GSNP	1934.17	1749.45	492.75	605.50	522.56	126.06
GSWE	2060.56	2948.64	698.96	665.34	911.03	163.26
GSWP	1631.54	1794.98	566.65	481.64	534.73	136.55
INE	2300.92	2786.10	1233.78	788.28	909.78	393.03
INP	2114.40	2455.98	1208.04	725.13	826.51	393.86
IWE	2078.03	2778.90	1270.84	729.15	930.84	383.06
IWP	2154.25	2790.88	1105.00	738.58	924.26	364.33
S x M						
SSN	1404.27	1603.05	924.95	522.41	600.63	358.76
SSW	1375.31	1328.73	956.14	506.47	500.84	368.99
GSN	2191.80	2388.36	634.70	721.19	756.50	173.00
GSW	1846.05	2371.81	632.80	573.49	722.86	149.90
IN	2207.66	2621.04	1220.91	756.70	868.14	393.44
IW	2116.14	2784.89	1187.92	733.86	927.55	373.69
S x P						
SSE	1504.24	1504.60**	945.13	568.75	569.01**	366.92
SSP	1275.34	1427.18	935.97	460.13	532.46	360.83
GSE	2255.00	2987.96	737.80	751.11	950.74	191.60
GSP	1782.85	1772.22	529.70	543.57	528.63	131.30
IE	2189.47	2782.50	1252.31	758.71	920.31	388.04
IP	2134.32	2623.43	1156.52	731.85	875.38	379.09
M x P						
NE	2085.03	2498.50	976.50	728.75	840.34	322.48
NP	1784.13	1909.80	877.21	604.78	643.18	308.57
WE	1880.78	2351.54	980.33	656.97	786.37	294.33
WP	1677.55	1972.09	870.92	552.25	647.81	286.49
System						
SS	1389.79**	1465.89**	940.55**	514.44**	550.74**	363.88**
GS	2018.93	2380.09	633.75	647.34	739.68	161.45
I	2161.90	2702.96	1204.42	745.28	897.84	383.57
Method						
N	1934.58	2204.15	926.85	666.77	741.76	308.40
W	1779.16	2161.81	925.62	604.61	717.09	297.53
Pattern						
E	1982.90*	2425.02**	978.41*	692.86**	813.35**	315.52
P	1730.84	1940.94	874.06	578.52	645.49	290.41

Contd.

Treatment	SE ± Summer 1983	SE ± Summer 1984	SE ± Kharif 1983	CD 5% Summer 1983	CD 5% Summer 1984	CD 5% Kharif 1983
Seed yield						
Treatment	273.49	241.93	106.44	567.22	501.76	220.75
S x M x P				NS	NS	NS
S X M	193.39	171.07	75.26	NS	NS	NS
S x P	193.39	171.07	75.26	NS	354.80	NS
M x P	157.90	139.68	61.45	NS	NS	NS
System	136.74	120.96	53.22	283.61	250.88	110.37
Method	111.65	98.77	43.45	NS	NS	NS
Pattern	111.65	98.77	43.45	231.56	204.84	90.12
Oil yield						
Treatment	89.80	91.53	38.12	186.24	189.84	79.06
S x M x P				NS	NS	NS
S x M	63.50	64.72	26.95	NS	NS	NS
S x P	63.50	64.72	26.95	NS	134.24	NS
M x P	51.84	52.85	22.00	NS	NS	NS
System	44.90	45.77	19.06	93.12	94.92	39.53
Method	36.66	37.37	15.56	NS	NS	NS
Pattern	36.66	37.37	15.56	76.03	77.50	NS

and 633.75 kg ha^{-1}) in their respective pure stands. Among the sole crops groundnut yielded significantly more than sunflower during the summer seasons. But, in <u>kharif</u> it yielded (633.75 kg ha^{-1}) significantly less than the sunflower (940.55 kg ha^{-1}).

Planting method did not influence the yields, though the narrow rows (1934.58, 2204.15 and 926.85 kg ha^{-1}) had an edge over the wider rows (1779.16, 2161.81 and 925.62 kg ha^{-1}) in the three seasons.

The equidistant row spacings (1982.90, 2425.02 and 978.41 kg ha^{-1}) were significantly superior to the paired row plantings (1730.84, 1940.94 and 874.06 kg ha^{-1}) in the three seasons.

Planting system and pattern interacted significantly during summer 1984. The higher order interactions were not significant.

The bivariate analysis of variance enabled the mean yields from the two component crops of each intercrop to be displayed jointly. These are presented in Fig.13 together with circles which correspond to 5% non-significance regions for the intercrop treatment means, a solid line which corresponds to the values from sole crop mean of sunflower and a pecked line for sole crop yield of groundnut. The total yield due to intercropping was significantly superior to the sole crop yield of both the components in the summer seasons. The pod yield from sole crop of groundnut was on par with the seed yield of sunflower grown as a sole crop during summer 1983, but was significantly superior during 1984 (Appendix III).

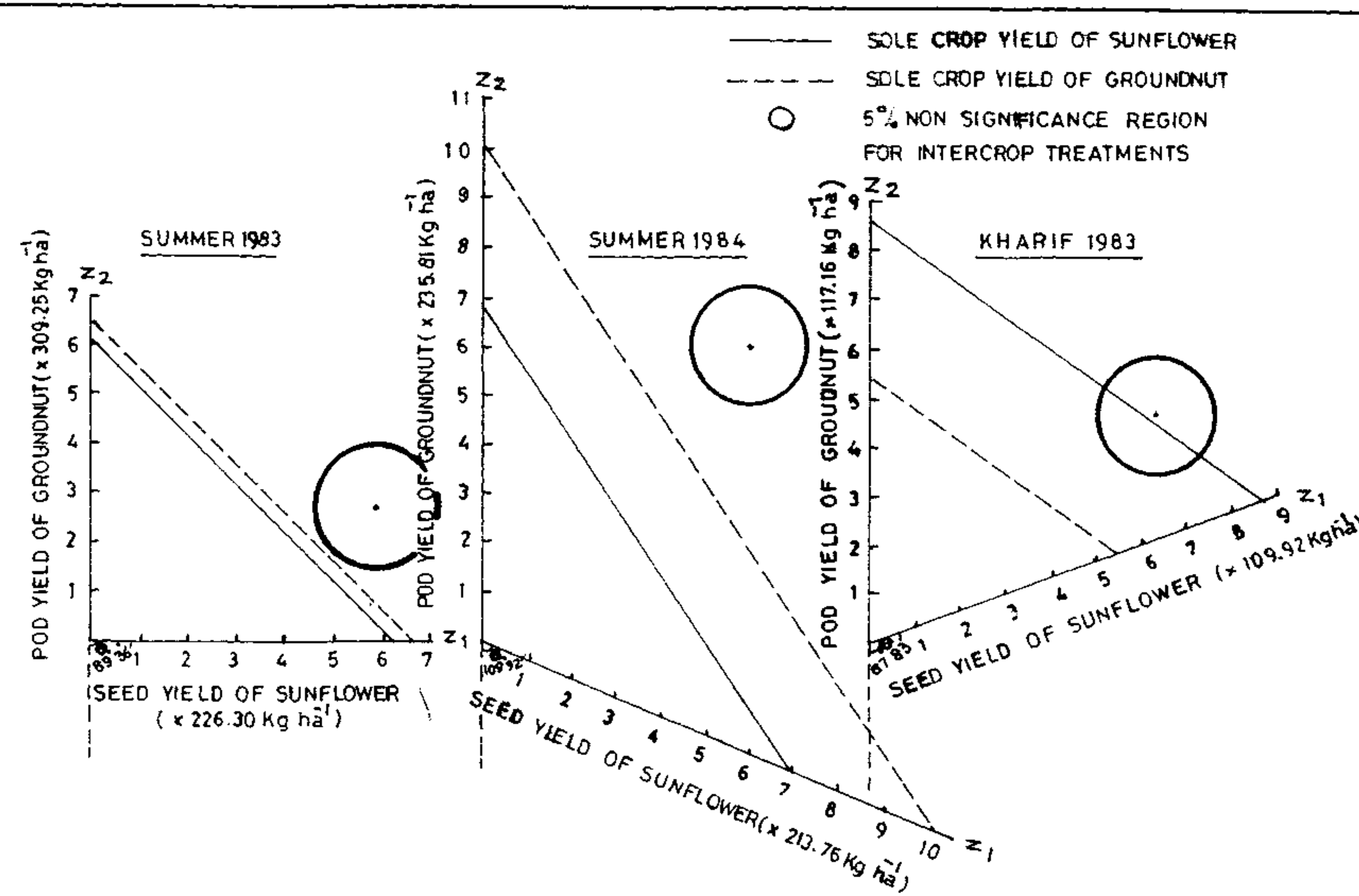


Fig:13 - MEAN TREATMENT YIELDS FROM BIVARIATE ANALYSIS IN SUNFLOWER-GROUNDNUT INTERCROPPING SYSTEM

In *kharif*, the total oilseeds due to intercropping did not improve and was on par with the sole crop yield of sunflower. While, the pod yield of sole groundnut was significantly the least.

4.3.2 Total oil yield (kg ha^{-1})

The treatment effects were highly significant in influencing the oil yield of sunflower and groundnut in pure stand and the total out-turn from the intercrop system (Table 42).

Among the sole crops the oil yield from groundnut in the summer seasons during 1983 (647.34 kg ha^{-1}) and 1984 (739.68 kg ha^{-1}) was significantly more than in the pure stand of sunflower (514.44 and 550.74 kg ha^{-1}). But, the total oil yield in intercrop system was enhanced to 745.28 and 897.84 kg ha^{-1} during 1983 and 1984 respectively. This accounted for a highly significant increase over the oil yield from either of the sole crops. In *kharif*, sole crop of groundnut (161.45 kg ha^{-1}) yielded significantly lesser quantity of oil than in the pure crop of sunflower (363.88 kg ha^{-1}) and the total oil yield from intercrop system (383.57 kg ha^{-1}). The oil yield from intercrop system was on par with the oil yield from sole crop of sunflower.

Planting method did not influence the oil yield significantly. The narrow rows performed slightly better (666.77, 741.76 and 308.40 kg ha^{-1}) than the wider rows (604.61, 717.09 and 297.53) with no statistical disparity in the three seasons.

The equidistant rows (692.86 and 813.35 kg ha^{-1}) were highly significant in their response to increased oil yield over the paired row pattern (578.52 and 645.49 kg ha^{-1}) in the summer seasons. The trend was similar even in the kharif season, but the differences were not significant between the equidistant (315.52 kg ha^{-1}) and paired rows (290.41 kg ha^{-1}).

The treatment effects between planting system and pattern interacted significantly during summer 1984, while, the higher order interactions were extinct in three seasons.

4.3.3 Net returns (Rs ha^{-1})

The net returns obtained by the differential planting system of sunflower and groundnut under varied planting geometry were significantly influenced during summer 1984 and kharif 1983 (Table 43).

The planting system indicated that the sole crop of groundnut fetched higher net returns of Rs 4114.40 and Rs 5709.60 ha^{-1} during summer 1983 and 1984 than the corresponding total net returns of Rs 3490.50 and Rs 5577.80 ha^{-1} from the intercrop system. The returns from sole crop of sunflower were least (Rs 2998.95 and 3303.36 ha^{-1}) during the two years. The net returns in the first year were, however, not significantly influenced by the planting system. But, subsequently during the second year, net returns from sole crop of sunflower were significantly less than the sole crop of groundnut or the total net returns from the intercrop system. The returns from sole crop of groundnut in turn were not significantly different from those in intercrop system. In *kharif*, sole crop of sunflower was highly remunerative with a net gain of Rs 1560.92 ha^{-1} than the intercrop system that accrued a total net return of Rs 379.76 ha^{-1}, while the sole crop of groundnut reckoned a net loss of Rs 705.98 over an hectare of planting. The increased net returns from sole sunflower over the intercrop system were highly significant.

Planting method did not influence the net returns. The net profits from the narrow (Rs 3850.40, 5012.59 and 401.45 ha^{-1}) and wider row widths (Rs 3218.84, 4714.59 and 421.67 ha^{-1}) were statistically at par.

The equidistant rows (Rs 4045.58, 5782.19 and 622.47 ha^{-1}) were significantly superior to the paired rows (Rs 3023.66, 3944.99 and 200.66 ha^{-1}) in the three seasons.

Among the first order of interactions, significant effects were observed between the planting system and pattern during summer, 1984 while the second order of interactions were not significant in any season.

4.3.4 Net return Re^{-1} (Rs)

The net profits per rupee investment on the cost of cultivation of sunflower or groundnut as sole crops or when sown together in intercropping system with varying spatial configuration were significantly influenced in the three seasons (Table 43).

Planting system indicated that the profits per rupee investment obtained from the sole crop of sunflower in the summer seasons during 1983 and 1984 worked out to Re 1.17 and 1.29. The corresponding returns from sole crop of groundnut were Re 0.96 and 1.33. The profits from the sole crops were statistically on par but were significantly superior to those from the intercrop system (Re 0.64 and 1.02) during the two years. In kharif the net return from a rupee spent on sole crop of sunflower was Re 0.71, while groundnut had a sheer loss of Re 0.20. Even intercropping groundnut in sunflower could not increase the net return which appeared next to nil with a mere profit of Re 0.08.

Planting method showed that the narrow row treatments were marginally better (Re 1.00 and 1.28) than the wider row treatments (Re 0.85 and 1.14) in the summer seasons. In kharif the net returns per rupee investment worked to Re 0.19 in the narrow rows and Re 0.20 in the wider rows.

The returns from equidistant rows were significantly higher (Re 1.06 and 1.43) than the paired row pattern (Re 0.78 and 1.00) in the summer seasons during 1983 and 1984. In kharif, the equidistant rows accrued a higher return of Re 0.25 than Re 0.14 in the paired pattern which however did not differ significantly.

The only significant interaction was observed between the planting system and methods during summer, 1984.

Table 43. Net returns (Rs) per hectare and net profit per rupee investment (Rs) from sole and intercrop system of sunflower and groundnut as influenced by varying crop geometry

Treat- ment	Net returns Rs ha^{-1}			Net profit Re^{-1} invest- ment (Rs)		
	Summer		Kharif	Summer		Kharif
	1983	1984	1983	1983	1984	1983
SSNE	3453.69	4168.33	1475.05	1.35	1.62	0.67
SSNP	2655.04	3535.65	1522.07	1.04	1.38	0.69
SSWE	3454.83	2748.07	1683.45	1.35	1.07	0.77
SSWP	2427.25	2761.41	1563.14	0.95	1.08	0.71
GSNE	5961.09	8166.42	-506.66	1.39	1.90	-0.05
GSNP	3782.03	3746.32	-1314.71	0.88	0.87	-0.38
GSWE	4246.19	7819.55	-439.26	0.99	1.82	-0.13
GSWP	2468.31	3106.15	-902.00	0.58	0.72	-0.26
INE	3937.17	5873.74	524.23	0.72	1.08	0.11
INP	3308.39	4585.08	371.05	0.61	0.84	0.08
IWE	3215.50	5917.08	660.34	0.59	1.08	0.14
IWP	3500.96	5935.33	-109.76	0.64	1.09	-0.01
S x M						
SSN	3056.86	3851.99	1498.56	1.19	1.50	0.68
SSW	2941.04	2754.74	1623.29	1.15	1.08	0.74
GSN	4871.55	5956.36	-741.83	1.13	1.38	-0.21
GSW	3357.25	5462.85	-670.13	0.78	1.27	-0.19
IN	3622.78	5229.41	447.64	0.66	0.96	0.09
IW	3358.23	5926.20	311.87	0.61	1.09	0.06
S x P						
SSE	3456.76	3458.20**	1579.24	1.35	1.35**	0.72
SSP	2541.14	3148.53	1542.60	0.99	1.23	0.70
GSE	5103.64	7992.98	-304.11	1.19	1.86	-0.09
GSP	3125.16	3426.23	-1107.86	0.73	0.79	-0.32
IE	3576.33	5895.40	592.28	0.65	1.08	0.12
IP	3404.67	5260.20	167.23	0.62	0.97	0.03
M x P						
NE	4452.31	6069.49	610.10	1.15	1.53	0.24
NP	3248.48	3955.68	192.80	0.84	1.03	0.13
WE	3638.84	5494.89	634.84	0.97	1.32	0.26
WP	2798.84	3934.29	208.51	0.72	0.96	0.15
System						
SS	2998.95	3303.36**	1560.92**	1.17**	1.29*	0.71**
GS	4114.40	5709.60	-705.98	0.96	1.33	-0.20
I	3490.50	5577.80	379.76	0.64	1.02	0.08
Method						
N	3850.40	5012.59	401.45	1.00	1.28	0.19
W	3218.84	4714.59	421.67	0.85	1.14	0.20
Pattern						
E	4045.58*	5782.19**	622.47*	1.06*	. 1.43**	0.25
P	3023.66	3944.99	200.66	0.78	1.00	0.14

Contd..

Treatment	SE ± Summer 1983	SE ± Summer 1984	SE ± Kharif 1983	CD 5% Summer 1983	CD 5% Summer 1984	CD 5% Kharif 1983
Net returns						
Treatment)	1113.53	1026.43	433.37	NS	2128.82	898.80
S x M x P)				NS	NS	NS
S x M	787.39	725.80	306.44	NS	NS	NS
S x P	787.39	725.80	306.44	NS	1505.30	NS
M x P	642.90	592.61	250.20	NS	NS	NS
System	556.76	513.22	216.68	NS	1064.41	449.40
Method	454.60	419.04	176.92	NS	NS	NS
Pattern	454.60	419.04	176.92	942.84	689.09	366.93
Net Profit Re^{-1}						
Treatment)	0.28	0.24	0.15	0.58	0.51	0.32
S x M x P)				NS	NS	NS
S x M	0.20	0.17	0.11	NS	NS	NS
S x P	0.20	0.17	0.11	NS	0.36	NS
M x P	0.17	0.14	0.09	NS	NS	NS
System	0.14	0.12	0.08	0.29	0.25	0.16
Method	0.11	0.10	0.06	NS	NS	NS
Pattern	0.11	0.10	0.06	0.24	0.21	NS

4.3.5 Relative net returns

The relative net return indices (RNR) of intercropping system over the sole crop components of sunflower and groundnut under varying crop geometry are presented in Table 44.

Planting system indicated that the RNR indices of intercropping over the sole crop of sunflower (1.11 and 1.41) were greater than the sole crop of groundnut (0.97 and 1.06) in the summer seasons. In *kharif* the RNR index was 1.45 over the sole crop of groundnut and 0.70 over sunflower. The RNR indices of the intercrop system over each of the sole crop components were highly significant during summer 1984 and *kharif*, 1983, while, there were no significant differences during summer, 1983.

The RNR indices due to intercropping in the narrow row widths (1.01 and 1.07) were less than in the wider rows (1.07 and 1.36) in the summer seasons. In *kharif*, intercropping in narrow row width treatment indicated a higher value (1.14) than in the wider row (1.01) spacing. The differences were significant during summer, 1984.

Planting pattern indicated that the RNR indices were greater in the paired rows (1.13, 1.32 and 1.13) than in the uniformly spaced row (0.95, 1.15 and 1.02) arrangement in the three seasons. But, the differences were not significant.

The crop and planting pattern showed a significant interaction of the RNR index in an intercrop system during summer 1984. The higher order interactions were not significant.

Table 44. Relative net return (RNR) indices due to intercropping over sole crops of sunflower and groundnut at varying crop geometry

Treatment	Summer		Kharif
	1983	1984	1983
SFNE	1.09	1.29	1.08
SFNP	1.17	1.17	1.26
SFWE	0.97	1.59	1.77
SFWP	1.22	1.58	1.32
GNNE	0.84	0.83	0.78
GNNP	0.94	1.13	1.43
GNWE	0.89	0.87	0.82
GNWP	1.19	1.40	1.16
SE ±	0.20	0.22	0.25
CD 5%	NS	0.47	0.54
C x M			
SFN	1.13	1.23	0.74
SFW	1.09	1.59	0.66
GNN	0.89	0.98	1.54
GNW	1.04	1.13	1.36
C x P			
SFE	1.03	1.44*	0.76
SFP	1.19	1.38	0.65
GNE	0.87	0.85	1.28
GNP	1.06	1.27	1.62
M x P			
NE	0.97	1.06	0.98
NP	1.05	1.15	1.30
WE	0.93	1.23	1.06
WP	1.20	1.49	0.96
SE ±	0.14	0.15	0.18
CD 5%	NS	0.33	NS
Crop			
SF	1.11	1.41**	0.70**
GN	0.97	1.06	1.45
Method			
N	1.01	1.11*	1.14
W	1.07	1.36	1.01
Pattern			
E	0.95	1.15	1.02
P	1.13	1.32	1.13
SE ±	0.10	0.11	0.13
CD 5%	NS	0.23	0.27

4.3.6 Land equivalent ratio

The partial land equivalent ratios (PLER) for each of the crop components in the intercrop system, viz., for sunflower (Ls) and groundnut (Lg) as well as the total land equivalent ratios (LER) of each intercrop treatment are depicted in Fig.14 and tabulated in Appendix V.

Among the different intercrop treatments sunflower sown in paired row pattern with wider rows registered maximum LER values of 1.55 and 1.79 during summer 1983 and 1984 respectively. The mean LER over the two seasons was 1.67. In *kharif*, the paired row pattern with narrow rows turned out to be the best with a maximum LER of 1.73.

The PLERs of sunflower (Ls) were in general better in the summer seasons than in *kharif*. In the narrow row treatment the Ls values were 0.96 and 0.99 with equidistant and paired pattern during summer 1983, while, 0.77 and 0.86 during summer, 1984, with an average of 0.86 and 0.92 over the two seasons. In wide rows the Ls values were 0.83 in the equidistant and 0.98 in the paired row pattern during summer, 1983. The corresponding values were 0.94 and 0.94 during summer, 1984 and thus averaged 0.88 and 0.96 over the two years.

The PLERs of groundnut (Lg) with the narrow rows in equidistant and paired pattern were 0.35 and 0.42 during summer 1983; 0.49 and 0.66 during summer 1984, while, the mean values were 0.42 and 0.54. The wider rows with an equidistant and paired pattern registered Lg values of 0.40 and 0.57 during summer 1983; 0.52 and 0.85 during summer 1984

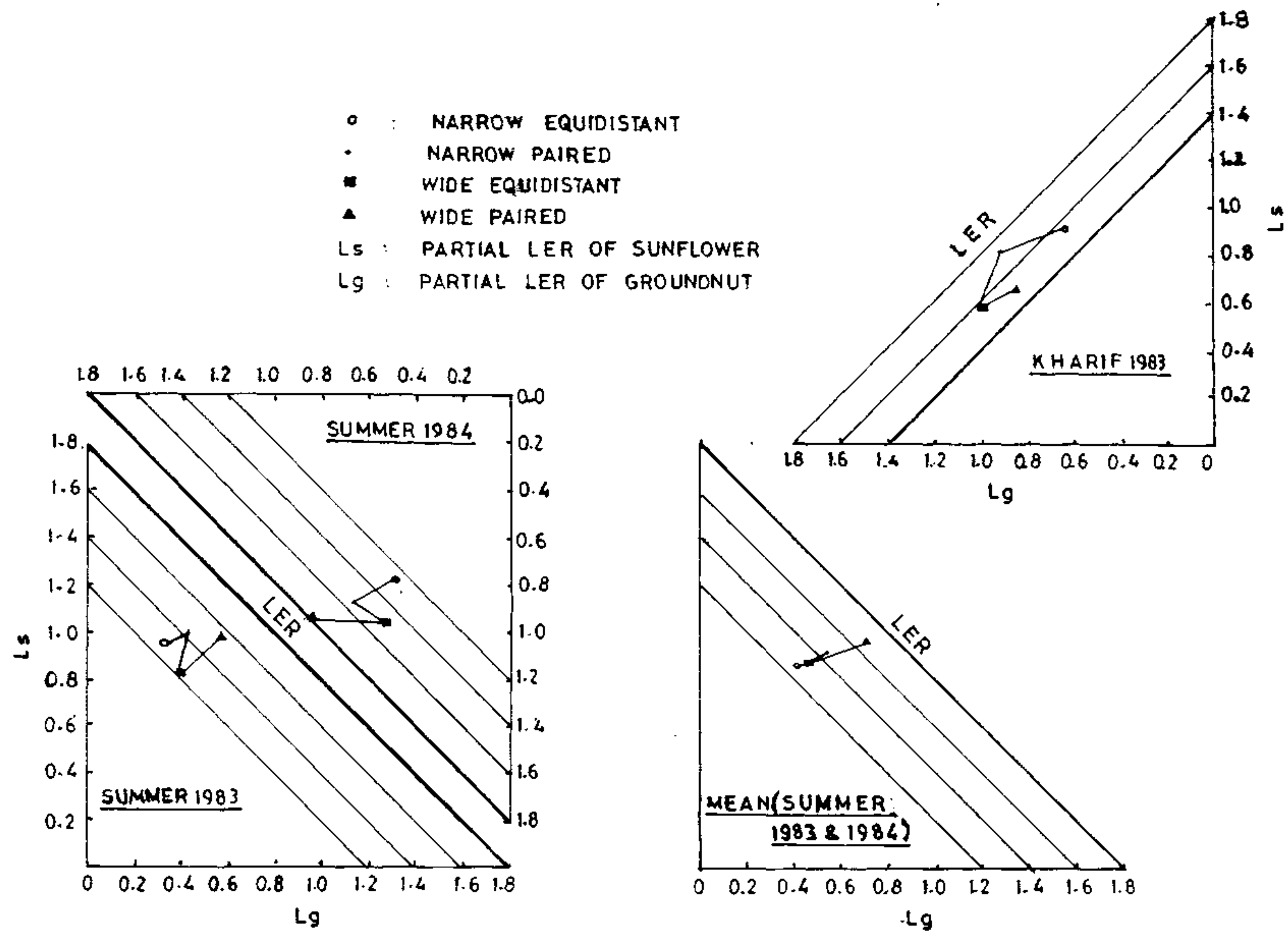


Fig: 14 - PARTIAL AND TOTAL LAND EQUIVALENT RATIOS IN SUNFLOWER - GROUNDNUT INTERCROPPING AS INFLUENCED BY PLANTING GEOMETRY with the corresponding mean values of 0.46 and 0.71 respectively.

The total LERs in the narrow row width treatment were 1.31 and 1.26 in the equidistant row configuration during summer 1983 and 1984 respectively. With paired pattern of row arrangement the corresponding values were raised to 1.41 and 1.52. The mean over two seasons indicated that the LER in the paired row pattern (1.46) was more than in equidistant rows (1.28). With wider row widths the equidistant and paired pattern showed that the LERs were 1.23 and 1.55 during summer 1983 while 1.46 and 1.79 during summer 1984 with a respective average of 1.34 and 1.67.

In kharif, the PLERs for sunflower (Ls) with narrow rows in equidistant and paired pattern were 0.90 and 0.80 while, for groundnut (Lg) 0.67 and 0.93. Thus the respective total LERs were 1.57 and 1.73. With wider rows the PLERs for sunflower (Ls) both in equidistant and paired pattern were much lower (0.59 and 0.66) than in the summer seasons, while there was an improvement for groundnut (1.00 and 0.86). The total LERs were thus 1.59 for equidistant and 1.52 for paired row pattern with wider rows.

4.3.7 Staple land equivalent ratios

The SLER values plotted against different standardized yields of sunflower (Ls) for the varying crop geometry in intercrop system are presented in Fig.15. It could be seen that all the intercrop treatments were more productive than the sole crops. Amongst the spatial configurations under test, the treatment wide-paired row pattern was most effective at

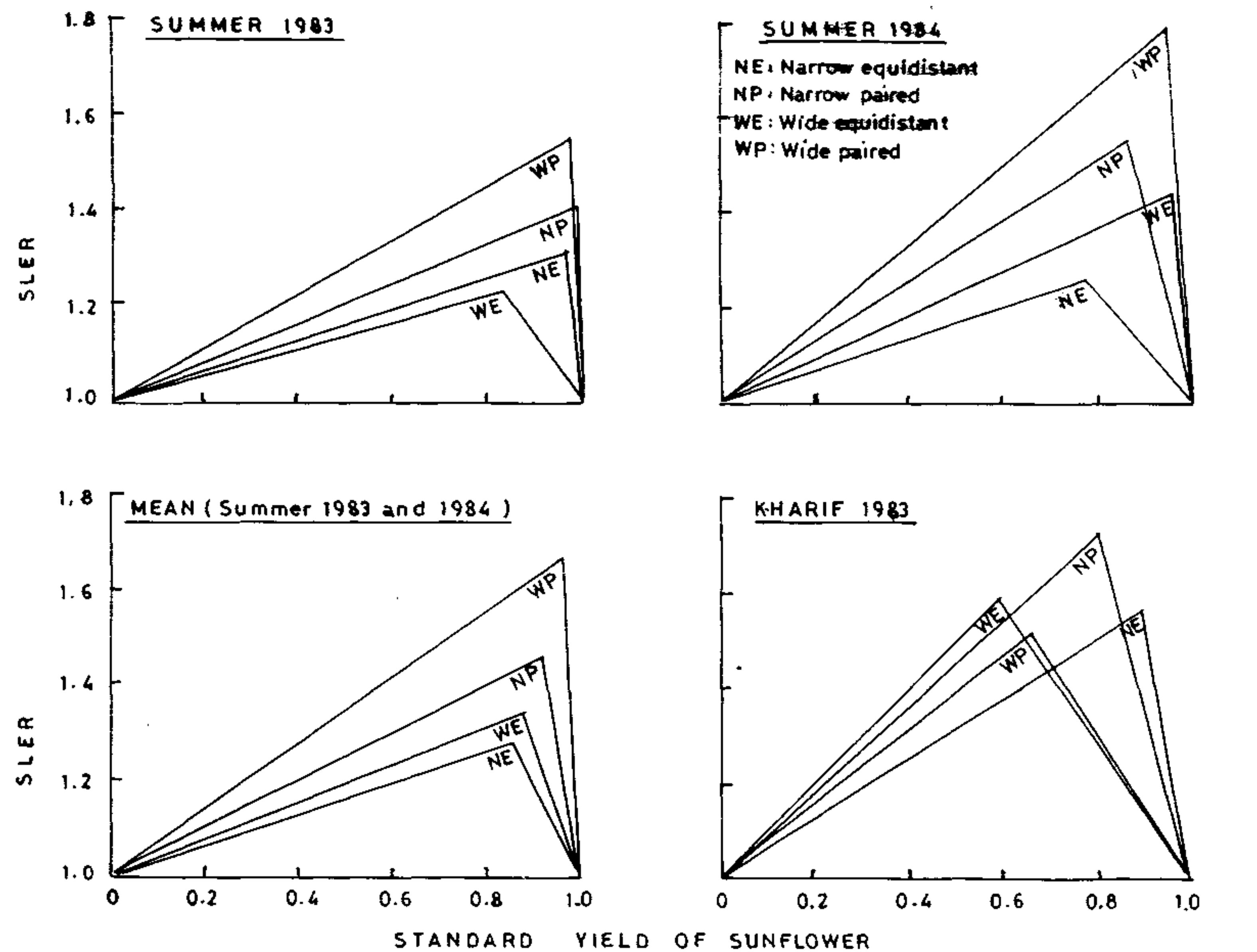


Fig: 15- STAPLE LAND EQUIVALENT RATIOS IN SUNFLOWER - GROUNDNUT INTERCROPPING AS INFLUENCED BY PLANTING GEOMETRY any desired yield level of sunflower in the summer seasons. Similar was the trend for the mean performance over the two years. With desired standardized yield levels as high as 0.98 and 0.94 during summer 1983 and 1984, the SLER values were 1.55 and 1.79 respectively. A reduction in the standardized yield of sunflower in the other spatial configurations was not commensurate with the SLERs obtained from the wide-paired row treatment.

In kharif, with an standardized yield of 0.80 for sunflower, the SLER values were maximum (1.73) in the narrow-paired row treatment. But, with the desired yield level increased to 0.90, the SLER was drastically reduced to 1.35. At this level, intercropping groundnut in the narrow-equidistant rows of sunflower was more advantageous since the SLER was much higher (1.57).

4.3.8 Calorific equivalents

The output of energy was largely influenced by the treatment effects (Table 45). The calorific values of sunflower in intercrop system were marginally reduced (8.10 m K cal ha^{-1}) during summer 1983. But, the reduction during summer 1984 and kharif 1983 (7.91 and 4.11 m K cal ha^{-1}) was highly significant compared to the sole crop (9.09 and 5.83 m K cal ha^{-1}). Planting method or pattern as well as the interaction effects were not significant.

Groundnut, when intercropped with sunflower registered a highly significant reduction in the energy output in the summer seasons both during 1983 and 1984 (4.85 and 8.07 m K cal ha^{-1}) compared to the sole crop (11.45 and 13.49 m K cal ha^{-1}). But, in <u>kharif</u> the calorific value of intercropped groundnut (3.08 m K cal ha^{-1}) was marginally lowered compared to its sole stand (3.59 m K cal ha^{-1}), planting method had no significant influence. Planting pattern revealed that the improvement in energy (12.73 and 4.92 m K cal ha^{-1}) due to equidistant row treatments was significant over that in paired row treatment (8.83 and 2.84 m K cal ha^{-1}) during summer, 1984 and <u>kharif</u> 1983. However, the reduction in energy due to paired row arrangement (7.53 m K cal ha^{-1}) was not significantly different from the equidistant pattern (8.77 m K cal ha^{-1}) during summer 1983. Planting system and pattern interacted significantly during summer 1984.

The total calorific equivalents due to intercropping were much higher than in the sole crop components of both the species. The increase in total calorific equivalents due to intercropping (12.95, 16.07 and 7.19 m K cal ha^{-1}) were highly significant over the sole crop of sunflower (8.62, 9.09 and 5.83 m K cal ha^{-1}) during the summer seasons of 1983, 1984 and <u>kharif</u> 1983. Significantly higher calorific values than the sole crop of sunflower were also recorded by the sole crop of groundnut both during summer 1983 and 1984 (11.45 and 13.49 m K cal ha^{-1}). But during <u>kharif</u> 1983 sunflower registered significantly higher calorific values (5.83 m K cal ha^{-1}) than the sole crop of groundnut (3.59 m K cal ha^{-1}).

Table 45. Calorific values (Million K cal ha^{-1}) from sole and intercrop system of sunflower and groundnut under varying crop geometry

Treatment	Summer 1983			Summer 1984			Kharif 1983		
	Sunflower	Groundnut	Total	Sunflower	Groundnut	Total	Sunflower	Groundnut	Total
SSNE	9.33	-	9.33	10.43	-	10.43	5.70	-	5.70
SSNP	9.79	-	9.79	9.45	-	9.45	5.77	-	5.77
SSWE	9.32	-	9.32	8.23	-	8.23	6.02	-	6.02
SSWP	7.73	-	7.73	8.25	-	8.25	5.83	-	5.83
GSNE	-	13.89	13.89	-	17.16	17.16	-	4.40	4.40
GSNP	-	10.97	10.97	-	9.92	9.92	-	2.79	2.79
GSWE	-	11.68	11.68	-	16.72	16.72	-	3.96	3.96
GSWP	-	9.25	9.25	-	10.18	10.18	-	3.21	3.21
INE	8.96	4.85	13.82	8.05	8.36	16.41	4.44	2.93	7.37
INP	8.05	4.62	12.68	8.09	6.53	14.62	4.64	2.61	7.25
IWE	7.77	4.68	12.45	7.73	8.67	16.75	3.55	3.96	7.51
IWP	7.61	5.25	12.86	7.79	8.70	16.49	3.83	2.76	6.59
SE ±	1.14	1.43	1.61	0.58	1.18	1.48	0.59	0.57	0.63
CD 5%	NS	3.07	3.34	NS	2.53	3.08	1.27	1.24	1.31
S x M									
SSN	8.70	-	8.70	9.94	-	9.94	5.73	-	5.73
SSW	8.53	-	8.53	8.24	-	8.24	5.93	-	5.93
GSN	-	12.42	12.42	-	13.54	13.54	-	3.60	3.60
GSW	-	10.47	10.47	-	13.45	13.45	-	3.59	3.59
IN	8.50	4.74	13.24	8.07	7.44	15.51	4.54	2.77	7.31
IW	7.69	4.96	12.65	7.76	8.69	16.62	3.69	3.36	7.05
S x P									
SSE	9.32	-	9.32	9.33	-	9.33**	5.86	-	5.86
SSP	7.91	-	7.91	8.85	-	8.85	5.80	-	5.80
GSE	-	12.78	12.78	-	16.94**	16.94	-	4.18	4.18
GSP	-	10.11	10.11	-	10.05	10.05	-	3.00	3.00
IE	8.37	4.76	13.13	7.89	8.52	16.58	3.99	3.45	7.44
IP	7.83	4.94	12.77	7.94	7.61	15.55	4.24	2.68	6.92
M x P									
NE	9.14	9.37	12.34	9.24	12.76	14.67	5.07	3.67	5.82
NP	8.06	7.80	10.57	8.77	8.22	11.33	5.20	2.70	5.27
WE	8.55	8.18	11.15	7.98	12.70	13.90	4.78	3.96	5.83
WP	7.67	7.25	9.95	8.02	9.44	11.64	4.83	2.99	5.21
SE ±	0.81	1.01		0.83	0.83		0.42	0.41	
CD 5%	NS	NS		NS	NS		NS	NS	
System									
SS	8.62	-	8.62**	9.09*	-	9.09**	5.83**	-	5.83**
GS	-	11.45**	11.45	-	13.49**	13.49	-	3.59	3.59
I	8.10	4.85	12.95	7.91	8.07	16.07	4.11	3.08	7.19
Method									
N	8.60	8.58	11.46	9.00	10.49	13.00	5.14	3.18	5.55
W	8.10	7.72	10.55	8.00	11.07	12.77	4.81	3.47	5.52
Pattern									
E	8.84	8.77	11.75*	8.61	12.73**	14.28**	4.92	3.31**	5.83**
P	7.87	7.53	10.26	8.40	8.83	11.48	5.02	2.84	5.24
SE ±	0.57	0.72		0.58	0.59		0.30	0.29	
CD 5%	NS	1.53		1.25	1.26		0.64	0.62	

Contd../-

Table 45. (Contd..)

Year	S x M or S x P		M x P		System		Method or pattern	
	SE ±	CD 5%	SE ±	CD 5%	SE ±	CD 5%	SE ±	CD 5%
Summer 1983	1.14	NS	0.93	NS	0.81	1.67	0.65	1.36
Summer 1984	1.05	2.18	0.86	NS	0.74	1.54	0.60	1.26
<u>Kharif</u> 1983	0.45	NS	0.36	NS	0.32	0.65	0.26	0.53

PLANT POPULATION

The relationship between seed/pod and oil yield per plant with planting densities each of sunflower and groundnut grown as sole or in intercrop system were best explained by the exponential models.

4.1 SUNFLOWER

The exponential decay curves indicated that the seed or oil yield per plant declined in a logarithmic order with natural base with increase in planting density of sunflower (Fig.16). The coefficients of determination for seed yield ranged from 0.90 to 0.98 in the summer seasons and from 0.75 to 0.91 in <u>kharif</u> (Table 46). For oil yield, the coefficients were in the range of 0.87 to 0.99 in the summer seasons and 0.75 to 0.89 in <u>kharif</u> (Table 48).

4.1.1 Seed yield

The tests for identity of the regression equations (F_1) were significant in the summer seasons except for the wider row treatment during summer 1983. The test for equality of intercepts (F_2) showed that the differences between sole and intercrops for each treatment were not significant. The slopes, however, differed significantly showing that the yield per plant in intercrop system declined at a faster rate than in the corresponding sole crop treatments as the density increased from lowest to the highest (F_3). During <u>kharif</u> 1983, the regression lines were identical, slopes were parallel and the elevations were not significantly different.

Table 46. Regression equations for seed yield on planting density of sunflower

Treat-ment	lny = lna + bx: lna	b	SE_b	r^2	F_1	F_2	F_3
			Summer 1983				
T_1	3.64789	-8.12000E-06x	2.48235E-09	0.95	19.82*	1.22	1314.15*
T_2	3.54012	-7.75000E-06x	5.13159E-09	0.97			
T_4	3.69059	-1.00142E-05x	6.84027E-07	0.90	2.33	6.24	266.23*
T_5	3.69408	-1.08750E-05x	5.94157E-07	0.94			
Overall					17.41**	15.32*	692.90**
			Summer 1984				
T_1	3.54944	-8.19220E-06x	2.40769E-07	0.98	48.42*	37.88	690.05*
T_2	3.36460	-7.13343E-06x	3.36195E-07	0.95			
T_4	3.45282	-8.86835E-06x	5.43264E-07	0.92	22.57*	7.34	305.15*
T_5	3.35804	-8.88666E-06x	4.70521E-07	0.94			
Overall	-	-	-	-	44.64**	15.05*	452.27**
			Kharif 1983				
T_1	2.38837	-8.08589E-06x	7.27289E-07	0.84	4.98	0.08	165.72
T_2	2.40831	-9.56396E-06x	6.46149E-07	0.91			
Pooled	2.39834	-8.82493E-06x	5.25264E-07	0.85			
T_4	2.43335	-8.55631E-06x	6.36667E-07	0.89	10.68	1.33	95.00
T_5	2.35939	-9.56453E-06x	1.15247E-06	0.75			
Pooled	2.39637	-9.06042E-06x	7.79880E-07	0.74			
Overall					5.15*	0.44	127.64**

F_1 = Test for identity of the regression equations
F_2 = Test for the equality of intercepts
F_3 = Test for parallelism

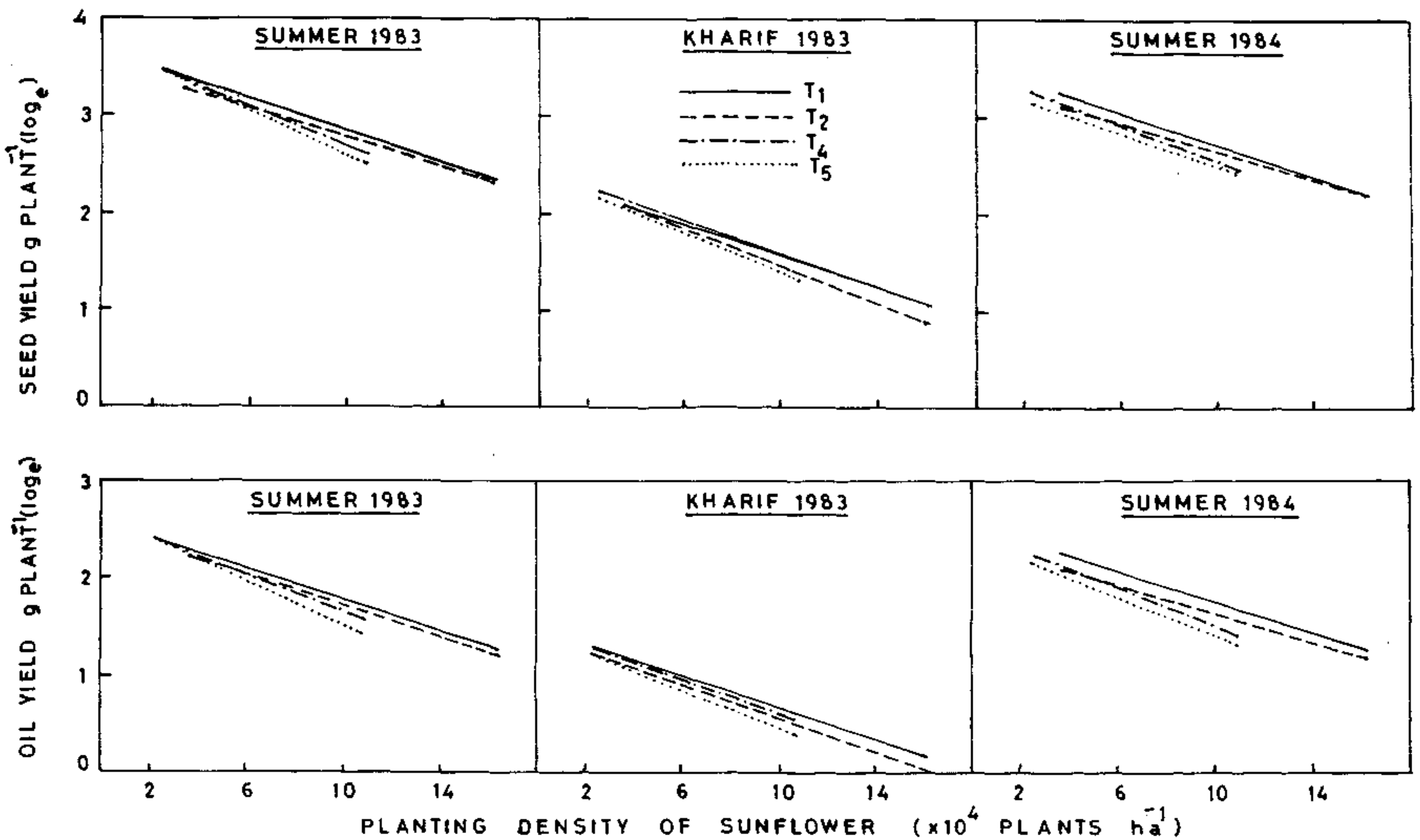


Fig:16-SEED OIL/YIELD PER PLANT (g $\log_e$) OF SUNFLOWER AS INFLUENCED BY PLANT POPULATION IN SOLE AND INTERCROP SYSTEM

The prediction equations (Table 47) showed that the yield per plant in sole crop declined from 28.78 to 10.28 g during summer 1983, from 26.02 to 9.20 g during summer 1984 and from 8.18 to 2.92 g during *kharif* 1983 as the plant population increased from 35467 to 162134 plants ha^{-1} in the narrow row treatment. When intercropped with groundnut the corresponding yields were estimated to decline from 26.18 to 9.80 g, from 22.46 to 9.10 g and from 7.92 to 2.36 g per plant in the respective seasons. The trend was similar in the wider row treatments. Yield in sole crop declined from a maximum of 31.63, 25.69 and 9.31 g at a density of 23616 plants ha^{-1} to a minimum of 13.36, 11.97 and 4.47 g per plant with a population of 107959 plants ha^{-1}. In intercrop system the weights reduced to 12.25, 10.86 and 3.71 g from a maximum of 31.10, 23.29 and 8.44g per plant.

The per hectare estimates plotted in Fig.17 indicated that the seed yield increased with density upto an estimated optimum plant population. In the narrow row treatment maximum sole crop yields of 1739.08 and 1562.44 kg ha^{-1} were recorded with an estimated optimum density of 123152 and 122067 plants ha^{-1} during summer 1983 and 1984 respectively. In intercrop system the corresponding maximum yields were 1636.24 and 1491.36 kg ha^{-1} with an optimum plant population of 129032 and 140185 plants ha^{-1}. In *kharif*, the maximum yield response to sole and intercrop system was attained with a planting density of 123672 and 104559 plants ha^{-1} registering an yield of 495.71 and 427.54 kg ha^{-1} respectively (Table 47). In wider row

Table 47. Exponent functions of seed yield estimated optimum density (X_{opt}) and yield (Y_{max} kg ha^{-1}) of Sunflower

Treat-ment	Yield plant^{-1} (g) y = a exp(bx) a	exp (bx)	X_{opt}	Y_{max} kg ha^{-1}
		Summer 1983		
T_1	38.3935	exp(-8.12000E-06x)	123152	1739.08
T_2	34.47105	exp(-7.75000E-06x)	129032	1636.24
T_4	40.06848	exp(-1.00142E-05x)	99858	1471.94
T_5	40.20856	exp(-1.08750E-05x)	91954	1360.16
		Summer 1984		
T_1	34.79382	exp(-8.19220E-06x)	122067	1562.44
T_2	28.92192	exp(-7.13343E-06x)	140185	1491.36
T_4	31.58934	exp(-8.86835E-06x)	112760	1310.39
T_5	28.73281	exp(-8.88666E-06x)	112528	1189.44
		Kharif 1983		
T_1	10.89571	exp(-8.08589E-06x)	123672	495.71
T_2	11.11516	exp(-9.56396E-06x)	104559	427.54
Pooled	11.00489	exp(-8.82493E-06x)	113315	458.75
T_4	11.39699	exp(-8.55631E-06x)	116872	490.00
T_5	10.58449	exp(-9.56453E-06x)	104552	407.10
Pooled	10.98323	exp(-9.06042E-06x)	110370	445.95

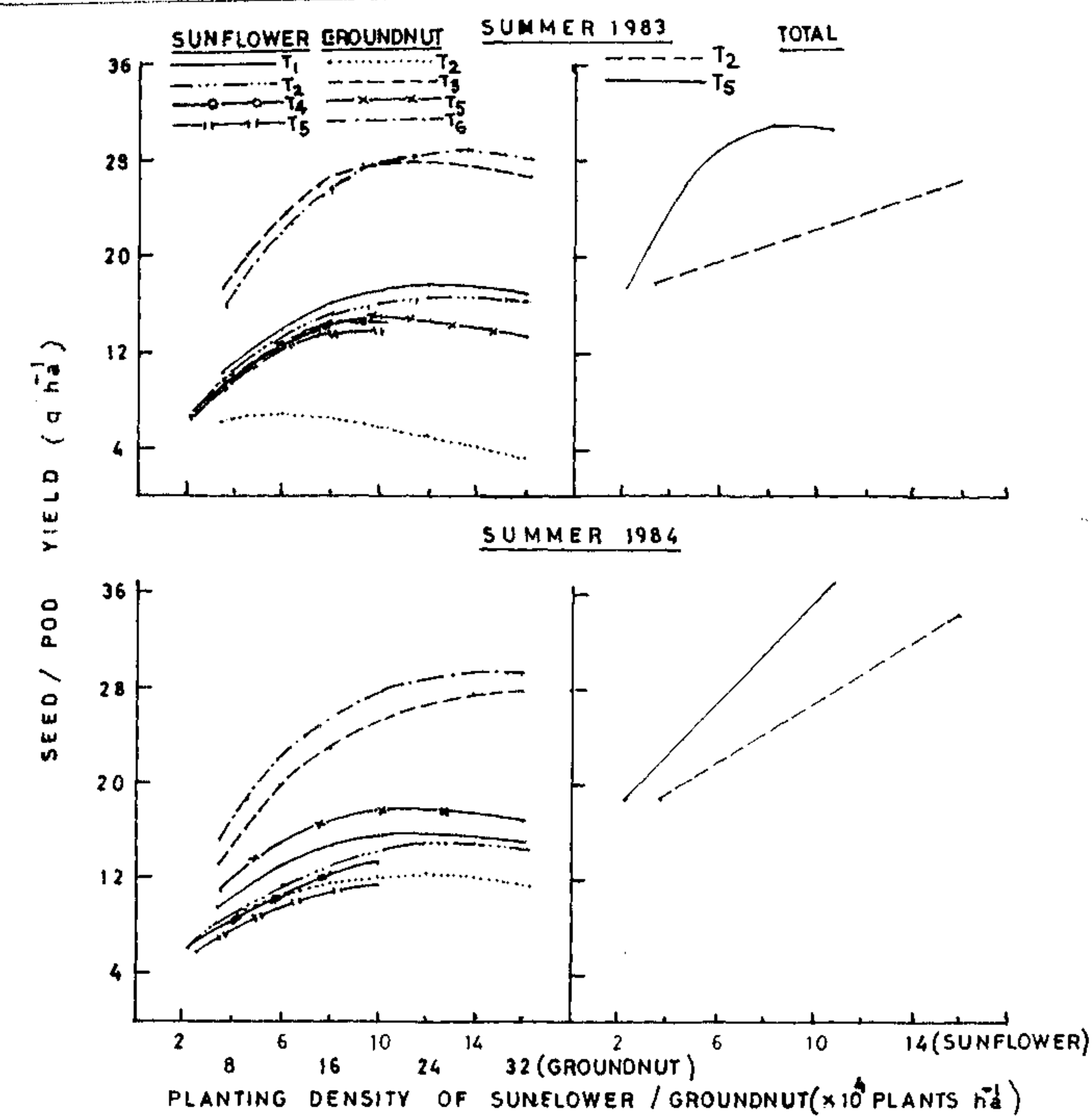


Fig: 17- SEED/ POD YIELD PER HECTARE OF SUNFLOWER/GROUNDNUT AS INFLUENCED BY PLANT POPULATION IN SOLE AND INTERCROP SYSTEM

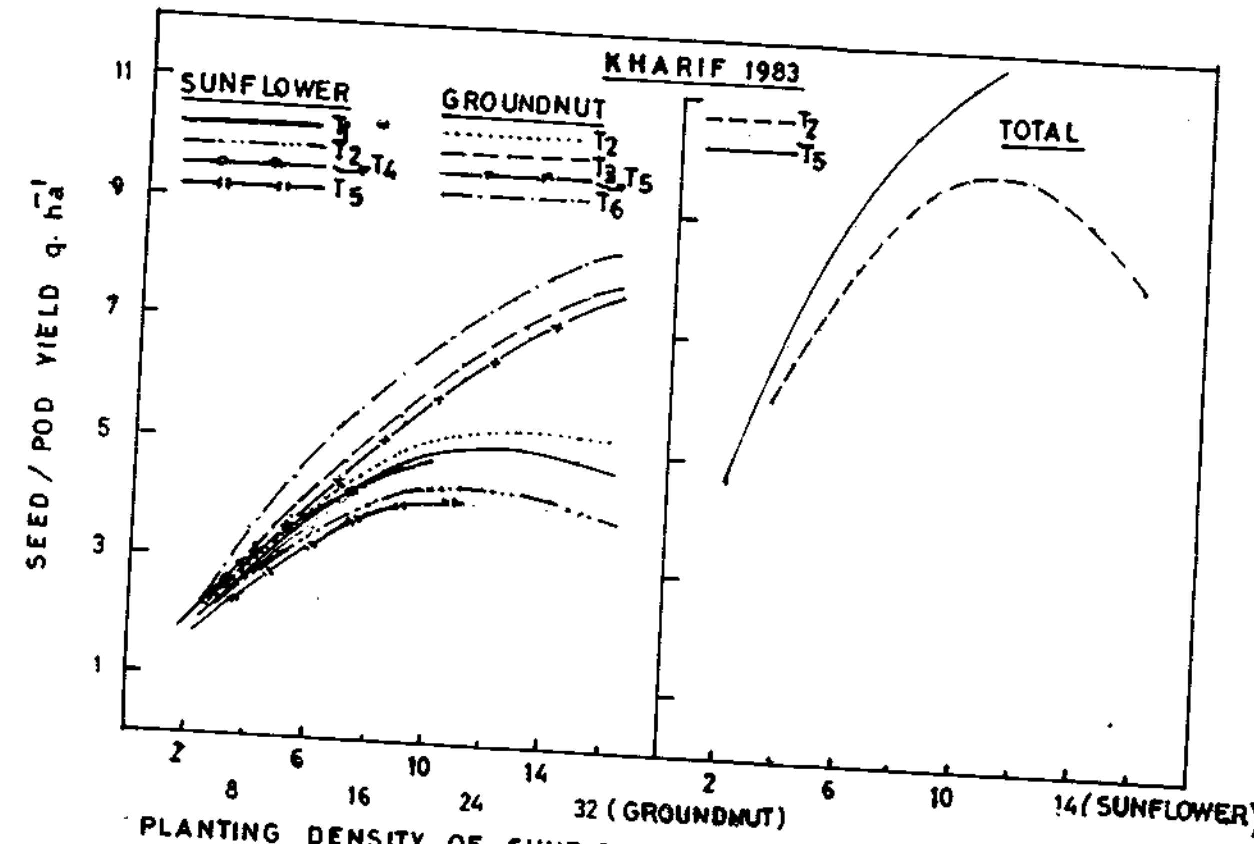


Fig:17(Contd)-SEED/POD YIELD PER HECTARE OF SUNFLOWER/GROUNDNUT AS INFLUENCED BY PLANT POPULATION IN SOLE AND INTERCROP SYSTEM treatment sole crop response to density was maximum upto 99858 plants ha^{-1} during summer 1983 and 112760 plants ha^{-1} during summer 1984 with a seed yield of 1471.94 and 1310.39 kg ha^{-1}. In intercrop system the maximum response was limited to a relatively lower density of 91954 and 112528 plants ha^{-1}. The maximum yields at these densities were 1360.16 and 1189.44 kg ha^{-1}. In the kharif season maximum yields in sole and intercrop system were 490.00 and 407.10 kg ha^{-1} which were obtained with a plant population of 116872 and 104552 plants ha^{-1}. Pooled regression functions in the kharif season for sole and intercrop performance in the narrow row treatment predicted a maximum yield of 458.75 kg ha^{-1} with 113315 plants ha^{-1}. With wider row treatment the maximum yield (445.95 kg ha^{-1}) was attained with a population of 110370 plants ha^{-1}.

4.1.2 Oil yield

The regression functions for oil yield per plant (Fig.16) were not identical only for the narrow row treatment during summer 1984, since the residual variances were significantly different (F1). The test for equality of intercepts (F2) indicated a homogeneity in the three seasons. The slopes were also parallel (F3) except for the significant variation in the narrow row treatment during the summer seasons (Table 48).

From the fitted power functions (Table 49) it is apparent that the oil yield per plant declined with an increase in planting density. In the narrow row treatment it declined from 10.22, 9.75 and 3.39 g during summer 1983, 1984 and kharif 1983 to a respective minimum of 3.61, 3.56 and 1.15 g in the sole crop. When intercropped it declined from 9.22, 8.48 and

Table 48. Regression equations for oil yield on planting density of Sunflower

Treatment	lny = lna + bx: lna	b	SE_b	r^2	F_1	F_2	F_3
			Summer 1983				
T_1	2.61526	-8.21000E-06x	2.63113E-09	0.99	18.43	1.75	1192.17*
T_2	2.49615	-7.75000E-06x	5.41225E-09	0.97			
Pooled	2.85825	-0.79885E-06x	3.95325E-07	0.97			
T_4	2.64400	-1.02438E-05x	7.38769E-07	0.89	1.48	0.23	217.71
T_5	2.62060	-1.04730E-05x	6.63322E-07	0.91			
Pooled	2.63230	-1.03584E-05x	5.01453E-07	0.90			
	$T_1 + T_2 + T_4 + T_5$				15.67**	16.61*	599.37**
			Summer 1984				
T_1	2.56237	-7.98968E-06x	2.93085E-07	0.97	27.21*	16.45	371.47*
T_2	2.39706	-7.29066E-06x	4.785731E-07	0.91			
T_4	2.45989	-9.03625-06x	7.47558E-07	0.87	11.34	1.11	181.20
T_5	2.40847	-9.95755E-06x	6.62558E-07	0.91			
Pooled	2.43418	-9.49690E-06x	5.97466E-07	0.84			
	$T_1 + T_2 + T_4 + T_5$				30.58**	5.57	253.12**
			Kharif 1983				
T_1	1.52226	-8.47495E-06x	7.54572E-07	0.85	5.02	0.53	149.83
T_2	1.46849	-9.04965E-06x	6.75707E-07	0.89			
Pooled	1.49537	-8.76230E-06x	5.47293E-07	0.84			
T_4	1.52336	-8.56558E-06x	7.99797E-07	0.83	9.25	1.57	83.63
T_5	1.439002	-9.29494E-06x	1.12719E-06	0.75			
Pooled	1.48118	-8.93026E-06x	8.01103E-07	0.72			
	$T_1 + T_2 + T_4 + T_5$				4.84*	0.70	114.08**

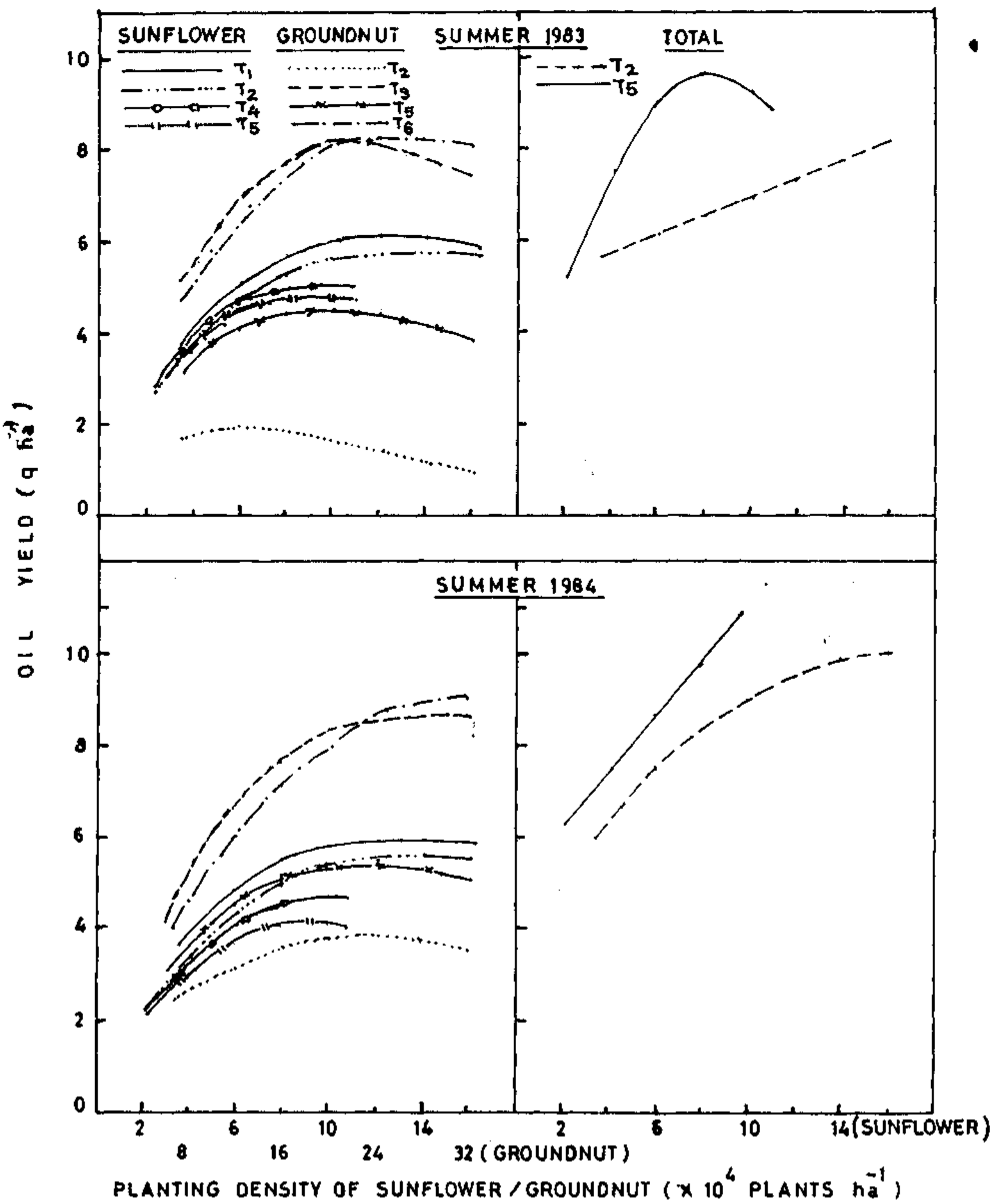


Fig: 18-OIL YIELD PER HECTARE OF SUNFLOWER / GROUNDNUT AS INFLUENCED BY PLANT POPULATION IN SOLE AND INTERCROP SYSTEM

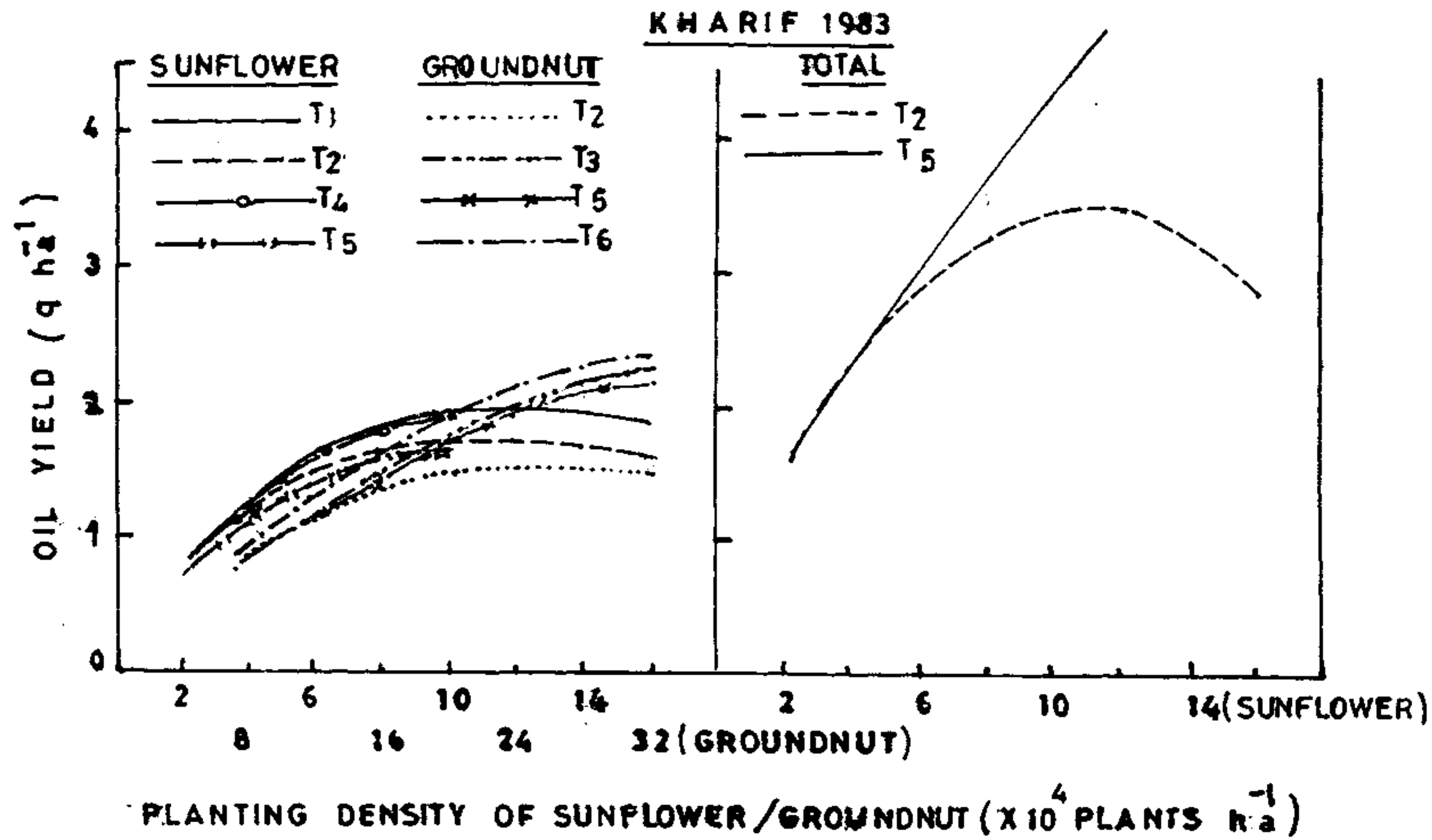


Fig:18(Contd)-OIL YIELD PER HECTARE OF SUNFLOWER/GROUNDNUT AS INFLUENCED BY PLANT POPULATION IN SOLE AND INTERCROP SYSTEM

Table 49. Exponent functions of oil yield, estimated optimum density (X_{opt}) and oil (Y_{max} kg ha^{-1}) of Sunflower

Treat-ment	Oil $plant^{-1}$ (g) $y = a\ exp(bx)$		X_{opt}	Y_{max} kg ha^{-1}
	a	exp(bx)		
		Summer 1983		
T_1	13.67077	exp(-8.21000E-06x)	121802	612.56
T_2	12.13568	exp(-7.75000E-06x)	129032	576.05
Pooled	12.93089	exp(-0.79885E-06x)	125179	595.45
T_4	14.06936	exp(-1.02438E-05x)	97620	505.26
T_5	13.74396	exp(-1.04730E-05x)	95483	482.77
Pooled	13.90571	exp(-1.03584E-05x)	96540	493.85
		Summer 1984		
T_1	12.96651	exp(-7.98968E-06x)	125161	597.03
T_2	10.99081	exp(-7.29066E-06x)	137161	554.58
T_4	11.70352	exp(-9.03625E-06x)	110665	476.46
T_5	11.11693	exp(-9.95755E-06x)	100426	410.70
Pooled	11.40646	exp(-9.49690E-06x)	105297	441.85
		Kharif 1983		
T_1	4.58257	exp(-8.47495E-06x)	117994	198.92
T_2	4.34267	exp(-9.04965E-06x)	110501	176.53
Pooled	4.46098	exp(-8.76230E-06x)	114125	182.93
T_4	4.58761	exp(-8.56558E-06x)	116746	197.02
T_5	4.21648	exp(-9.29494E-06x)	107585	166.88
Pooled	4.39813	exp(-8.93026E-06x)	111978	181.17

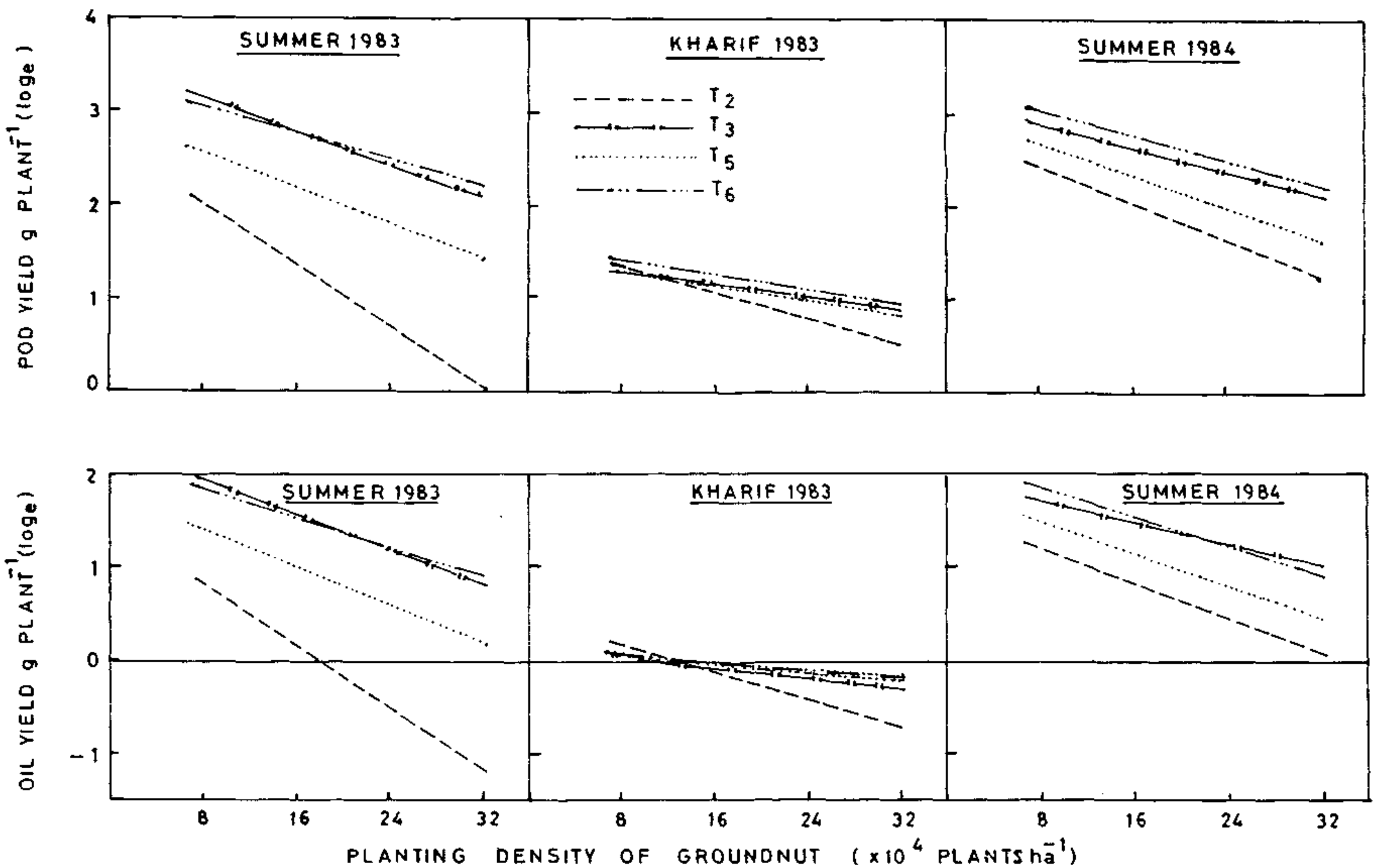


Fig:19- POD/OIL YIELD PER PLANT OF GROUNDNUT AS INFLUENCED BY PLANT POPULATION IN SOLE AND INTERCROP SYSTEM

3.16 g to 3.45, 3.36 and 0.99 g per plant. In the wider row treatment the oil yield over a density range of 23616 and 107959 plants ha^{-1} declined from 11.06, 9.50 and 3.75 g to 4.60, 4.30 and 1.79 g per plant. The corresponding decline in intercrop system was from a maximum of 10.76, 8.81 and 3.40 g to a minimum of 4.37, 3.74 and 1.52 g per plant.

Oil yield per hectare increased with planting density upto an estimated optimum (Fig.18). Maximum oil yield of sunflower (576.05, 554.58 and 176.53 kg ha^{-1}) in intercrop system with narrow row treatment was obtained with an optimum plant population of 129032, 137161 and 110501 plants ha^{-1} during summer 1983, 1984 and kharif 1983 respectively. Conversely, the sole crop yielded 612.56, 597.03 and 198.92 kg ha^{-1} with a relatively lower plant population of 121802 and 125161 plants ha^{-1} in the summer seasons while with a higher density of 117994 plants ha^{-1} in kharif compared to that in intercrop system. The sole crop in wider row treatment performed better (505.26, 476.46 and 197.02 kg ha^{-1}) with a relatively higher density of 97620, 110665 and 116746 plants ha^{-1} than in intercrop system.

4.2 GROUNDNUT

The power functions plotted in Fig.19 for the per plant pod and oil yield revealed that the performance of groundnut in intercrop system was distinctly different from the sole crop. The fitted equations for pod yield per plant accounted for 80 - 95% of the total sum of squares in the summer seasons and 54 - 89% in *kharif*. For oil yield the coefficients of determination ranged from 0.79 to 0.95 in the summer seasons and from 0.46 to 0.88 in *kharif*.

4.2.1 Pod yield

Highly significant differences were observed amongst the regressions fitted for the pod yield per plant of groundnut in sole/intercrop system either in narrow or wider rows in the summer seasons. In *kharif* the plots of yield in sole and intercrop system were identical in the narrow row treatment. The intercepts were not significantly influenced in any season. The slopes were parallel but were significantly different only for the wider row treatment during summer 1984 (Table 50).

The prediction equations (Table 51) showed that the per plant yield in sole crop with narrow row treatment declined from 24.29, 19.05 and 3.69 g with 70735 plants ha^{-1} to a minimum of 8.20, 8.57 and 2.44 g with 323362 plants ha^{-1} in the three seasons. The estimated yield per hectare (Fig.17) increased from 1718.15, 1350.33 and 261.00 kg with the lowest density to a maximum of 2819.49, 2770.61 and 933.34 kg ha^{-1} with an optimum density of 232775, 316032 and 612917 plants ha^{-1}. In intercrop system yield per plant declined from 8.25, 11.79 and 4.05 g to 1.00, 3.48 and 1.60 g. The yield per hectare increased from 583.56, 833.96 and 286.47 kg upto an optimum density of 119401, 207774 and 273942 plants ha^{-1} with a maximum yield of 655.46, 1266.80 and 528.56 kg.

Table 50. Regression equations for pod yield on planting density of Groundnut

Treatment	$\ln y = \ln a + bx$: $\ln a$	b	SE_b	r^2	F_1	F_2	F_3
			Summer 1983				
T_2	2.70285	-8.37508E-06x	8.12346E-07	0.82	387.58**	42.80	125.32
T_3	3.49425	-4.29599E-06x	2.13477E-07	0.95			
T_5	2.98937	-4.90210E-06x	2.25003E-07	0.95	274.21**	41.22	277.24*
T_6	3.37123	-3.74427E-06x	2.65802E-07	0.90			
Overall					287.52**	30.34**	153.89**
			Summer 1984				
T_2	2.80781	-4.81292E-06x	4.96727E-07	0.80	148.13**	15.98	102.02
T_3	3.17098	-3.16423E-06x	2.55640E-07	0.87			
T_5	3.03535	-4.31168E-06x	3.20588E-07	0.89	129.24**	20.29	170.37
T_6	3.31271	-3.44855E-06x	2.81713E-07	0.87			
Overall					108.68**	15.30*	125.82**
			Kharif 1983				
T_2	1.65725	-3.65040E-06x	2.73077E-07	0.89	12.17	14.92	91.64
T_3	1.42052	-1.63154E-06x	3.14543E-07	0.54			
Pooled	1.54142	-2.65898E-06x	2.54062E-07	0.69			
T_5	1.38218	-1.59292E-06x	1.89019E-07	0.76	49.58*	29.64	80.25
T_6	1.60448	-2.01887E-06x	1.83751E-07	0.84			
Overall					21.42**	13.64*	88.09**

Table 51. Exponent functions of pod yield, estimated optimum density (X_{opt}) and pod yield (Y_{max} kg ha^{-1}) of groundnut

Treatment	Yield $plant^{-1}$ (g) y = a exp(bx) a	exp (bx)	X_{opt}	Y_{max} kg ha^{-1}
		Summer 1983		
T_2	14.92224	exp(-8.37508E-06x)	119401	655.46
T_3	32.92550	exp(-4.29599E-06x)	232775	2819.49
T_5	19.87321	exp(-4.90210E-06x)	203994	1491.32
T_6	29.11436	exp(-3.74427E-06x)	267074	2860.50
		Summer 1984		
T_2	16.57361	exp(-4.81292E-06x)	207774	1266.80
T_3	23.83097	exp(-3.16423E-06x)	316032	2770.61
T_5	20.80819	exp(-4.31168E-06x)	231928	1775.37
T_6	27.45953	exp(-3.44854E-06x)	289976	2929.25
		Kharif 1983		
T_2	5.24487	exp(-3.65040E-06x)	273942	528.56
T_3	4.13927	exp(-1.63154E-06x)	612917	933.34
Pooled	4.67121	exp(-2.65898E-06x)	376084	646.27
T_5	3.98360	exp(-1.59292E-06x)	627777	919.99
T_6	4.97526	exp(-2.01887E-06x)	495326	906.58

In wider row treatment, pod yield per plant of the sole crop weighed 22.34, 21.51 and 4.31 g at the lowest density and declined to a respective minimum of 8.67, 9.00 and 2.59 g at the highest density. The per hectare production followed an increase from 1580.22, 1521.51 and 304.86 kg at the lowest density to a maximum of 2860.50, 2929.25 and 906.58 kg with an optimum population of 267074, 289976 and 495326 plants ha^{-1}. The intercrop yield per plant declined from a maximum of 14.05, 15.33 and 3.56 g to a minimum of 4.06, 5.16 and 2.38 g. The estimated yields were 993.83, 1084.37 and 251.82 kg with a plant population of 70735 plants ha^{-1}. Yields increased with density upto a maximum of 1491.32, 1775.35 and 920.00 kg ha^{-1} with an estimated optimum of 203994, 231928 and 627777 plants ha^{-1}.

4.2.2 Oil yield

The residual variances for the response curves were heterogeneous (F1) in the three seasons. The equality of intercepts was observed due to sole/intercrop system both in narrow and wide row treatment comparisons. The slopes were significantly different in the wider row treatment only during summer 1983 (Table 52).

Oil yield per plant in sole crop with narrow row treatment was estimated to decline from 7.28 to 2.30 g during summer 1983, from 5.73 to 2.80 g during summer 1984 and from 1.06 to 0.60 g during <u>kharif</u> 1983 as the plant population increased from 70735 to 323362 plants ha^{-1} (Table 53). In

Table 52. Regression equations for oil yield on planting density of groundnut

Treatment	lny = lna + bx		SE_b	r^2	F_1	F_2	F_3
	lna	b					
			Summer 1983				
T_2	1.49455	-8.43945E-06x	7.25099E-07	0.85	433.51**	45.08	149.62
T_3	2.30739	-4.55406E-06x	2.59499E-07	0.93			
T_5	1.82068	-5.06472E-06x	2.36733E-07	0.95	274.21**	41.22	277.24*
T_6	2.17304	-3.90771E-06x	2.86487E-07	0.89			
Overall					306.64**	30.11**	173.22**
			Summer 1984				
T_2	1.57404	-4.63557E-06x	4.48120E-07	0.82	199.97**	24.16	101.46
T_3	1.94662	-2.83137E-06x	2.74669E-07	0.82			
T_5	1.83746	-4.29833E-06x	3.29982E-07	0.88	105.41**	17.75	141.02
T_6	2.13959	-3.58115E-06x	3.82242E-07	0.79			
Overall					120.59**	20.61*	118.32
			Kharif 1983				
T_2	0.46019	-3.74359E-06x	2.93455E-07	0.88	23.34*	21.57	84.26
T_3	0.17169	-1.57768E-06x	3.57969E-07	0.46			
T_5	0.13670	-1.59884E-06x	2.21350E-07	0.69	46.07*	28.34	70.24
T_6	0.35828	-2.05378E-06x	2.08656-07	0.81			
Overall					18.84**	16.74*	79.77**

Table 53. Exponent functions of oil yield, estimated optimum density (X_{opt}) and oil yield (Y_{max} kg ha^{-1}) of groundnut

Treat-ment	Yield plant^{-1} (g) y = a exp(bx) a	exp (bx)	X_{opt}	Y_{max} kg ha^{-1}
		Summer 1983		
T_2	4.45733	exp(-8.43945E-06x)	118491	194.29
T_3	10.04822	exp(-4.55406E-06x)	219584	811.69
T_5	6.17606	exp(-5.06472E-06X)	197444	448.60
T_6	8.78494	exp(-3.90771E-06x)	255904	827.02
		Summer 1984		
T_2	4.82610	exp(-4.6355E-06x)	215723	382.99
T_3	7.00499	exp(-2.83137-06x)	353185	910.15
T_5	6.28050	exp(-4.29833E-06x)	232648	537.52
T_6	8.49595	exp(-3.58115E-06x)	279239	872.75
		Kharif 1983		
T_2	1.58437	exp(-3.74359E-06x)	267123	155.69
T_3	1.18730	exp(-1.57768E-06x)	633842	276.84
T_5	1.14648	exp(-1.59884E-06x)	625453	263.79
T_6	1.43086	exp(-2.05378E-06x)	486907	256.30

intercrop system oil per plant declined from 2.45 to 0.29, from 3.47 to 1.08 and from 1.21 to 0.47 g in the respective seasons. The per hectare oil yield estimation at the lowest density in sole crop was much higher (515.00 and 405.56 kg ha^{-1}) than in the intercrop system (173.30 and 245.93 kg ha^{-1}) in the summer seasons (Fig.18). But in <u>kharif</u>, oil yield per hectare due to sole (74.98 kg ha^{-1}) and intercropping system (86.00 kg ha^{-1}) were not markedly different. A maximum oil yield of 811.69, 910.15 and 276.84 kg ha^{-1} was realised with an optimum population of 219584, 353185 and 633842 plants ha^{-1} in the sole crop. In intercrop system maximum oil yield of sunflower was limited to 194.29, 382.99 and 155.69 kg ha^{-1} with a population of 118491, 215723 and 267123 plants ha^{-1}.

In wider row treatment yield per plant of the sole crop declined from 6.66 to 2.48 g during summer 1983, from 6.59 to 2.68 g during summer 1984 and from 1.24 to 0.76 g during <u>kharif</u> 1983 as the density increased from 70735 to 323362 plants ha^{-1}. The per hectare oil yield raised from 471.31 kg at the lowest density to 827.02 kg at an optimum density of 255904 plants ha^{-1} during summer 1983. Oil yield with 70735 plants ha^{-1} during summer 1984 was 466.68 kg while it increased with density to a maximum of 872.75 kg with 279239 plants ha^{-1}. In the <u>kharif</u> season, it increased from 87.52 to 256.30 kg with an optimum population of 486907 plants ha^{-1}. Oil yield per plant of groundnut when intercropped declined from 4.32, 4.63 and 1.02 g to 1.20, 1.56 and 0.68 g during summer 1983, 1984 and <u>kharif</u> 1983. The corresponding per hectare oil yield estimates were found to increase from 305.32, 327.78 and 72.42 kg to a maximum of 448.60, 537.52 and 263.79 kg at optimum plant populations of 197444, 232648 and 625453 plants ha^{-1} respectively.

4.3 INTERCROPPING

4.3.1 Total productivity of oilseeds

Response to total oilseeds production in the intercrop system with narrow rows was linear in the summer seasons and quadratic in kharif. In wider row treatment, the response was quadratic during summer 1983 and kharif 1983, but was linear during summer 1984 (Table 54).

In the narrow row treatment the total oilseeds production increased from 17.39 q ha^{-1} during summer 1983 and from 18.52 q ha^{-1} during summer 1984 to a maximum of 24.42 and 35.0 q ha^{-1} with increase in density from 35467 to 162134 plants ha^{-1}. In kharif the total oilseed production was raised from 6.02 q ha^{-1} with the lowest density to a maximum of 10.08 q ha^{-1} with an estimated optimum population of 108920 plants ha^{-1}. In the wider row treatment, the total productivity increased from 17.95 and 4.84 q ha^{-1} with a plant population of 23616 plants ha^{-1} to a maximum of 31.07 and 11.67 q ha^{-1} during summer and kharif 1983 with an estimated respective optimum density of 88830 and 107959 plants ha^{-1}. During summer 1984 the total oilseeds were triggered from 18.97 to 36.60 q ha^{-1} as the density increased from 23616 to 107959 plants ha^{-1}.

Table 54. Regression functions for total seed and oil yield (q ha^{-1}) in a sunflower-groundnut intercropping system

Treatment	a	b_1	b_2	SE_{b1}	SE_{b2}	r^2
			Seed yield (kg ha^{-1})			
			Summer 1983			
T_2	15.42600	5.54669E-05x	-	-2.24313E-10	-	0.78
T_5	6.74948	5.47188E-04x	-3.08056E-09x^2	1.39811E-04	1.25983E-09	0.78
			Summer 1984			
T_2	13.90620	1.30170E-04x	-	6.642713E-06	-	0.94
T_5	14.03535	2.09155E-04x	-	6.09339E-06	-	0.98
			Kharif 1983			
T_2	1.13245	1.63325E-04x	-7.49745E-10x^2	1.40267E-05	8.42104E-11	0.94
T_5	1.03322	1.78945E-04x	-7.44731E-10x^2	2.42566E-05	2.18575E-10	0.95
			Oil yield (q ha^{-1})			
			Summer 1983			
T_2	4.92567	2.07099E-05x	-	3.60863E-06	-	0.66
T_5	1.27884	2.04947E-04x	-1.25070E-09x^2	2.99520E-05	2.69920E-10	0.89
			Summer 1984			
T_2	3.29784	6.59015E-05x	-2.78846 E-10x^2	2.33936E-05	1.40804E-10	0.80
T_5	4.69883	6.42949E-05x	-	3.01142E-06	-	0.95
			Kharif 1983			
T_2	0.50409	5.50233E-05x	-2.53167E-10x^2	9.89209E-06	5.95396E-11	0.77
T_5	0.87769	3.43878E-05x	-	1.91511E-06	-	0.93

4.3.2 Total oil yield

The total oil yield due to intercropping in narrow rows showed a linear increase during summer 1983, but followed a quadratic response during summer 1984 and *kharif* 1983. It increased with density from 5.64 to 8.28 q ha^{-1} during summer 1983. In the subsequent summer during 1984 and *kharif* 1983 the total oil yield increased from 6.02 and 2.12 q ha^{-1} with a population of 35467 plants ha^{-1} to a maximum of 9.91 and 3.52 q ha^{-1} with an optimum population of 154030 and 108669 plants ha^{-1}.

In wider row treatment the response was quadratic during summer 1983, but was linear during summer 1984 and *kharif* 1983. The total oil yield realised from inter-crop system with a population of 23616 plants ha^{-1} was 5.30, 6.22 and 1.70 q ha^{-1}. In the summer season during 1983 it increased with density upto 81932 plants ha^{-1} registering a total quantity of 9.57 q oil ha^{-1}. During summer 1984 and *kharif* 1983, oil yield increased to a maximum of 11.64 and 4.59 q ha^{-1} with the highest planting density of 107959 plants ha^{-1}.

CHAPTER V

DISCUSSION AND CONCLUSIONS

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Plant population and the spatial arrangement of plants within a crop community are the most important agronomic considerations that deserve research attention for yield improvement of any crop. In wide spaced crops utilisation of the inter-row spaces for intercropping is another agronomic strategy that suggests in itself as an attractive proposition to attain the turning objective of increasing the overall productivity. To this end, the findings emerging from the field evaluation on "crop geometry studies in sunflower in association with groundnut", elaborated in the previous chapter are discussed in this section.

WEATHER AND ITS EFFECTS ON THE CROPS

The crop growth period was hot and dry during the summer seasons. The meteorological data indicated that the temperatures and the relative humidity did not show a marked variation between the two years. The mean maximum and minimum temperatures increased gradually from sowing till harvest of the crops. The weather in general was more humid in the initial stages than in the later part. During summer 1983, a rainfall of 14.8 mm was received at the preflowering stage of the sunflower crop while 33.6 mm was obtained after its harvest by the groundnut crop. In the second year fairly well distributed rainfall of 59.1 mm was received between the period from late vegetative phase till harvest of the sunflower crop. Later groundnut received a precipitation of only 3.8 mm prior to its harvest.

As expected the *kharif* season was wet with high relative humidity and lower temperatures. Owing to the overcast weather, the hours of bright sunshine per day were also much less than in the summer seasons. The rains were unusually high and prolonged causing much of the cultural operations to be performed difficult. About 81% (740.5 mm) of the total annual rainfall (916.7 mm) was received during the crop growth period. This alone accounted for a higher precipitation than the total mean annual rainfall of 694 mm for this region. Due to continuous rains the adjacent well was overflooded with the result that the experimental site was inundated. Though a continuous drain was provided, the water logged conditions persisted due to the incessant rains and the simultaneous overflow of water.

Both the crops received a set back in the wet season because of the continued heavy rains with the accompanying oxygen stress due to the water logged conditions. Sojka and Stolzy (1981) also reported that the unrelieved oxygen stress due to flooding quickly damages the plants and eventually reduces the crop yields, since plant roots require adequate oxygen to respire and carry on various metabolic activities. They demonstrated that the availability of oxygen to the roots of sunflower as measured by the oxygen diffusion rate (ODR) is lowered by flooding while the leaf diffusive resistance (Rs) increases indicating the closure of stomata as a result of oxygen shortage which is physically excluded from the soil pores. Stomatal closure due to flooding prevents the normal transpirational cooling of plant tissues, creates an heat stress and will reduce the photosynthesis.

Sunflower was free from major pest or disease incidence in the three seasons. A negligible incidence of basal stem rot incited by Sclerotinia sclerotiorum (Lib.) de Bary was noticed in the kharif season. Groundnut, was heavily infested with the leaf miner (Aproaerema modicella Deventer) during the summer seasons while in kharif probably it was washed off due to heavy rains as reported by Reddy (1982). However, it is an interesting feature to record that the sole crop of kharif groundnut was severely infested with the pod boring insect larvae of the wireworms (Diabrotica sp.). These larvae fed on the developing kernels and rendered the pods empty leaving the symptom only of a minute hole on the shells. However, groundnut pods in the intercrop system with sunflower were completely free of this pest ravage. Reddy (1982) also reported that the incidence of this pest is confined to rainfed groundnut.

The effect of planting seasons was well distinguished on the crop yields. Sunflower in the summer seasons yielded over one and a half times more seed and oil yield than in kharif. Similarly, the performance of groundnut was also relatively poor in the kharif yielding two and a half to three times less of pods and three to four times lesser quantity of oil than in the summer seasons. Reddy (1982) and Mahapatra et al. (1985) also reported that the pod yields of summer groundnut are three to four times more than in the kharif season with possible advantages on growth and development due to favourable climatic conditions.

CROP GEOMETRY STUDIES

SUNFLOWER

General pattern of growth and development

The vegetative and reproductive growth characteristics were in general independent of the treatment effects. Plant height measured over the crop growth period followed the typical sigmoid growth curve. After emergence, the seedlings increased in height slowly in the initial stage during the vegetative phase. But from the late vegetative phase at 30 days there was a very rapid take-off in the elongation of stems till the commencement of reproductive growth at 45 days (bud stage). Increase in height further continued albeit at a relatively lesser rate till flowering but virtually ceased with little growth being apparent past this stage. On an average plants had attained about 96, 97 and 91% of the final height in the summer seasons during 1983, 1984 and kharif, 1983 by the time the crop was in flowering stage. This implies that the meristematic activity is most intense from the late vegetative phase till flowering. This observation lends support to the findings of Rao (1974) and English et al. (1979).

The photosynthetic unit per plant represented by the number of leaves, leaf area display and the dry mass per se increased with crop age upto flowering. But subsequently there was a decline as a result of dying back and cessation of leaf formation owing to senescence. Earlier studies indicated that the number of leaves per plant increased with crop age upto seed setting stage (Rao, 1974) while the leaf expansion continued only upto flowering (Iliev and Ilieva, 1980 and Hocking and Steer, 1983 a).

Phytomass accumulation and distribution

Partitioning of dry matter into various above-ground parts of the plant illustrated in Fig. 20 showed that the phytomass of leaves followed the pattern of leaf area at different stages of crop growth. The decline in weight after flowering was very fast during the summer seasons but was very little due to the continued moist conditions in kharif. Increase in phytomass accumulation of leaves upto flowering followed by a decline in the later stages confirms the findings of Rao (1974), English et al. (1979), Hocking and Steer (1983 a) and Steer and Hocking (1984).

Accumulation of dry matter in the stem increased with crop age upto flowering in the summer seasons and upto seed setting stage in kharif. Later, there was a marginal decline as the crop approached maturity. The cessation of phytomass accumulation after flowering might have been the resultant cause of the shifts in assimilate allocation to the developing reproductive sinks. This observation is in line with the findings of English et al. (1979) and Hocking and Steer (1983 a) but contradicts that of Rao (1974) who recorded an increase in dry weight of stem till maturity. The cumulative phytomass acquisition of leaves and stem followed an increasing pattern upto flowering followed by a steep decline towards harvest. In kharif phytomass acquisition in the vegetative

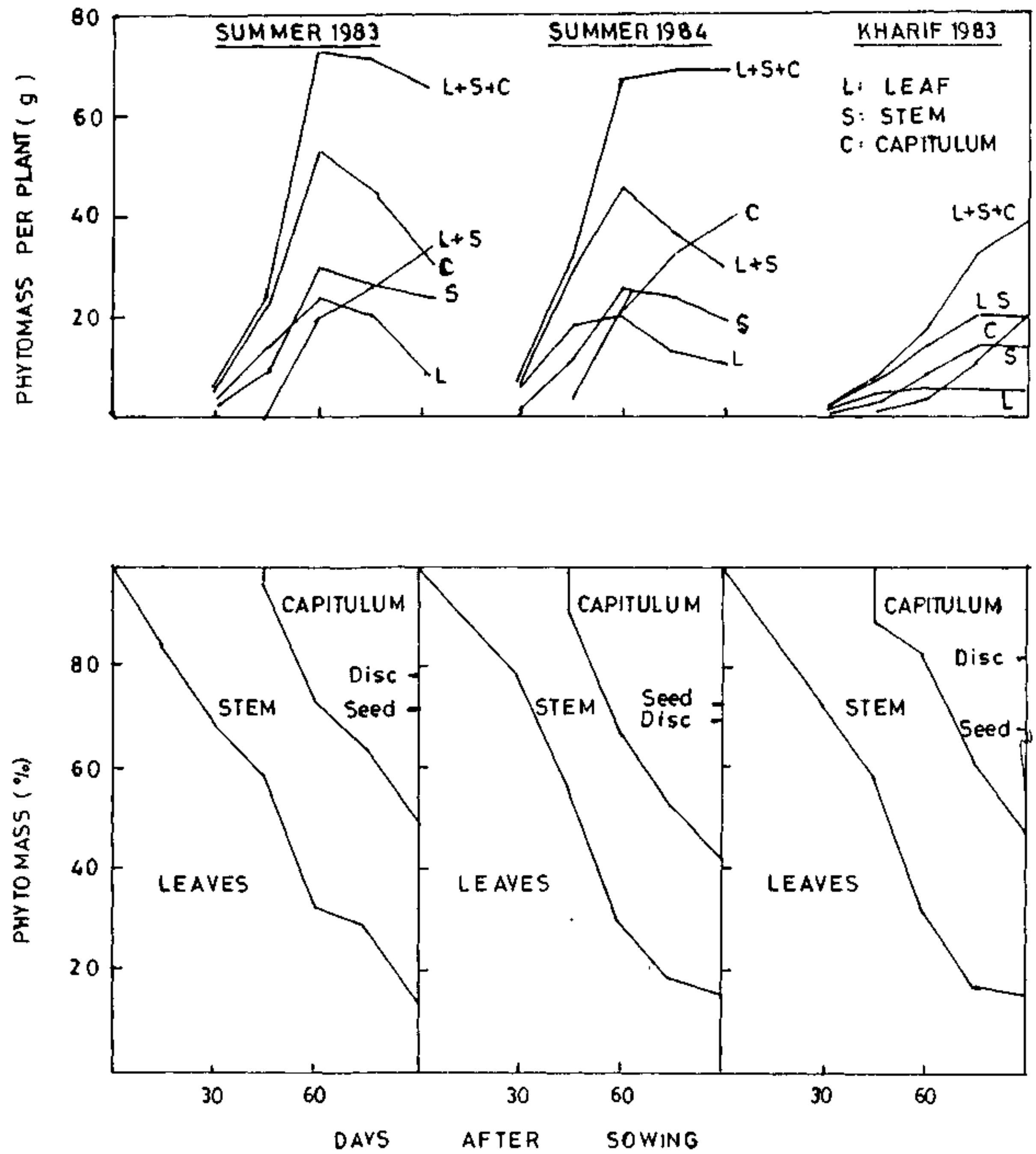

Fig:20-ABSOLUTE AND RELATIVE PARTITION OF PHYTOMASS IN SUNFLOWER parts increased markedly till seed setting stage, but, followed a slight decline at harvest.

The gain in mass of the capitulum followed an upsurge since the formation of flower buds till the physiological maturity was attained. The most rapid rate of increase was recorded from flower bud formation till flowering in the summer seasons and during the period between flowering and seed filling stage in kharif. The total phytomass in the above-ground shoot was maximum at about flowering to seed filling stages in the summer seasons while at maturity in kharif. Iliev and Ilieva (1980) suggested that the losses of accumulated phytomass at the end of growing period may be attributed to the (1) volatile aromatic principles (2) liquid losses (nectar, sap exudation, glandu lar secretion, etc.) (3) falling-off of leaves, stamen, pollen, etc. and (4) outflow of organic matter (K_2O) through the roots back into the soil (exo-osmosis).

The distribution of phytomass in different plant parts as per cent of the shoot (Fig.20) indicated that initially, leaf dry weight increased at the fastest rate but after bud stage, the main stem accounted for an increasing proportion of total above-ground dry weight. Following initiation the proportion of inflorescence was very low while it increased at a very fast rate representing 49.86, 57.20 and 50.30% of the total shoot weight at maturity in the summer seasons during 1983, 1984 and during kharif 1983 respectively. At harvest partitioning of the capitulum into seed and disc indicated that the seed accounted for 28.32, 27.02 and 31.70% of the total phytomass accumulated by the shoots. Discs had accounted for 21.54, 30.18 and 18.60% of the total share during the respective seasons. English *et al*. (1979) reported that the seed represented about 55% of the weight of inflorescence but only 33% of the dry weight of the total plant at physiological maturity. Hocking and Steer (1983 a) reported that the seeds made up 38% of the dry weight of a mature plant.

Growth characteristics, yield components, seed and oil yield

The effect of planting system on the growth, development and the phytomass accumulation at different phenological stages of the crop growth was not substantial. The plant height, number of leaves, leaf area and the phytomass accumulation in the above ground plant parts of sunflower were little affected when intercropped with groundnut. Though plant height is not an yield component it is positively correlated with yield (Amable, 1980) and is reported to have a strong relationship with the number of leaves per plant (Green, 1980). Lack of response to plant height in the present investigation might perhaps be due to its phototropic response. The little variation in number of leaves per plant indicates that the photosynthetic activity of sunflower was almost uniform both in a solitary and mixed stand at various stages of crop growth. Differences in capitulum diameter, number of seeds per plant, thousand seed weight and yield per plant recorded at harvest were also hard to distinguish due to planting system. The prolific growth habit of the crop and its ability to extract moisture and nutrients from deeper layers of the soil probably makes it a dominant species in the intercrop system competing for the available resources equally well as in sole situation. Capitulum diameter determines the surface generating area that produces the seed. Since diameter of the capitulum did not differ significantly, it is obvious that the number of seeds per disc were almost equal. The little variation in thousand seed weight indicates that the translocation of photosynthates into the seeds were not adversely affected as to cause a significant decrease due to intercropping. Hence, the yield per plant did not vary significantly.

Crop geometry appears to have little or no influence on the growth and yield contributing parameters. Wider rows tended to bring in a slight improvement in plant height, number of leaves, leaf area and phytomass accumulation per plant at various phenophases while that of capitulum diameter and thousand seed weight at maturity during the kharif season. But, in the summer seasons, the favourable effects were tilted in the narrow row widths with a marginally better performance compared to the wider rows. Nevertheless, the effect of planting method in general was not statistically significant in the three seasons. Variation in the row width and consequently the plant spacing thus had no marked influence on the crop growth and yield attributing characters in sunflower. Vijayalakshmi *et al*. (1975) reported that the plants in narrow row widths grew taller while the number of leaves were not significantly different from the wider rows. The present investigations confirm the findings of Char and Dasgupta (1977) that the variation in row width and plant spacing at a constant plant population did not influence the plant height, number of leaves, test weight and number of seeds per plant. But with increased row widths and decreased plant spacing at a constant or different level of planting density Akhanda *et al.* (1979) and Smith *et al.* (1981) observed that the plants tended to increase in height while there was no effect on the head diameter.

The effect of planting pattern in uniformly spaced row widths or in paired pattern did not influence the growth or yield attributing characteristics significantly. The significant variation recorded at certain growth stages in different treatments might have occured due to the possible sampling error.

Planting system indicated that the seed yield of sunflower was not markedly affected by the associated growth of groundnut as an intercrop component in the summer seasons. Yield realization from sunflower in intercrop system was 94 and 87% of that in the sole crop during summer 1983 and 1984 respectively. Thus sunflower could withstand the imposed competitive stress by the interplanted groundnut with a mere loss in yield of only about 6-13% as in the sole stand. This explains that the prolific growth habit of the crop makes it a dominant species. Analogous to this finding Singh and Singh (1977), Ujjanaiah *et al.* (1981) and Nikam *et al.* (1984) also reported that groundnut in intercrop system did not significantly reduce the seed yield of sunflower. But opposing these results Chandrasekhar and Morachan (1979 a), Umapathy *et al.* (1980) and Sindagi (1982) observed that groundnut competed with sunflower and reduced its yield significantly. In *kharif* season during 1983 seed yield of sunflower in the intercrop system was reduced by 30%

compared to the sole crop and the differences were significant. In addition to the competitive effects, the greater loss in seed yield by way of more severe lodging in the intercrop system than in the sole crop may perhaps be attributed to the significant differences in yield. The differences in lodging were due to the differences in drainage of inundated water in the experimental units. Since a greater part of the soil was covered by the combined forage, drainage was comparatively more tedious than in the sole crop. As a sequel the greater moisture retention caused more severe lodging of sunflower in the intercrop system.

Planting method did not influence the seed yield significantly. Narrow rows tended to yield marginally better with 6 and 13% higher yield than the wider rows during summer, 1983 and 1984 respectively. Also in the kharif season a change in the row width accounted for a mere difference of 6.37%. Lack of response to variation in spacing within or between the rows at a constant plant population was also reported by Vijayalakshmi et al. (1975) and Char and Dasgupta (1977).

Planting pattern indicated that the paired row arrangement of sunflower was not advantageous in that the seed yield did not differ significantly from the equidistant rows. During summer 1983 and 1984, the uniformly spaced crop yielded 11 and 2.5% more and even in kharif the differences were hard to distinguish with an edge of 1.82%. Singh and Singh (1977) and Radford (1978) also reported that the pairing had no advantage over the uniformly spaced rows in sunflower. While, Robinson et al. (1982) and Nikam et al. (1984) reported that the yields were reduced in paired row planting of sunflower. Hoes and Huang (1976) reported that the plants should be spaced as uniformly as possible lest there would be increased chances of contact with sclerotia by the increased mass of roots in closer spacings resulting in a greater number of diseased plants.

The oil per cent was not influenced by the treatment effects. It is imperative from the data gathered on the neutroperiodism that the similar pattern of nutrient absorption probably did not cause a major change in the synthesis of oil due to planting system, method or pattern of row arrangement. The observations recorded by Ramaswamy et al.(1974b), Vijayalakshmi et al. (1975), Beard et al. (1976), Char and Dasgupta (1977) and Smith et al. (1981) also concur the present finding that the row width or plant spacing variables are not critical to significantly vary the oil percentage in sunflower achenes. Oil yield is a function of per cent oil and the seed yield. Oil yield per plant, therefore, did not differ significantly due to different treatments, although the sole crop had an edge over the intercrop system and the narrow rows tended to yield marginally better than the wider rows. Oil yield per hectare was not influenced by the crop geometry both in sole and intercrop situations in the summer seasons. The pooled analysis however showed that the oil content of sunflower achenes in intercrop system was significantly less than in the sole crop. The narrow and equidistant rows were also found to be highly significant in yielding more oil than the wider rows and the paired row pattern respectively. But, Smith et al.(1981) reported a decline in oil yield as the row width was increased from 41 to 91 cm. In the *kharif* season, though the oil per cent of sunflower achenes remained unchanged, a reduction in seed yield when intercropped led to a significant decline in the oil yield per hectare to the extent of 30.65%. But planting method or pattern had no marked influence since the seed yield per hectare as well as oil per cent were not substantially influenced by these treatments.

NEUTRO-PERIODISM

a. Nutrient composition

The nutrient composition curves (Figs. 7 - 9) showed that the tissue concentration of sunflower in the individual plant parts followed a markedly different pattern for each of the three elements viz., nitrogen, phosphorus and potassium. However the concentration of any element was not influenced markedly by the planting system, method or pattern of row arrangement.

Nitrogen

The nutrient concentration curves (Fig.7) indicated that the nitrogen per cent in leaves and stem was more in the vegetative phase at 30 days and declined progressively with crop age till maturity. In heads, the concentration dropped off from bud formation till seed filling stage and then remained almost the same at harvest though there was a slight increase in the first season. These findings lend support to the data collected earlier by several authors (Rao, 1974; Kalra and Tripathi, 1980; Hanumantha Rao and Vidyasagar, 1981 and Mathers and Stewart, 1982). But, Reddy and Patil (1983) reported that the per cent nitrogen in sunflower plants increased upto flowering and then declined appreciably at harvest. Throughout the growth of crop, leaves had the highest concentration of nitrogen. But at harvest capitulum had a higher proportion of per cent nitrogen than the leaves and stem. The concentration in stem was intermediate throughout the phenological stages. The nutrient concentration curves of Mathers and Stewart (1982) also demonstrated a similar phenomenon of nitrogen concentration in different plant parts of sunflower.

Phosphorus

The tissue concentration of phosphorus in leaves increased until the seed filling stage and then dropped off rapidly. Phosphorus absorption in the stem followed a similar pattern, but the peak concentration both in stem and capitulum was attained at flowering (Fig.8). Shifts in the tissue concentration of this element during the reproductive stage might probably be due to translocation in the reproductive sinks. While, an increase in the dry weight of capitulum after flowering might have rendered low concentration values due to dilution in this tissue. Increase in the concentration of phosphorus in stem upto flowering was also recorded by Hanumantha Rao and Vidya Sagar (1981). But, the tissue concentration in leaves was reported to be maximum in the vegetative phase which declined at flowering and again increased at harvest. These results contradict the reports that the phosphorus concentration in leaves, stem and head decline with crop age (Rao, 1974; Mathers and Stewart, 1982 and Hocking and Steer, 1983 b).

Capitulum, generally had a higher concentration than the leaves while stems had the least. This observation falls in line with the pattern indicated by the nutrient concentration curves of Mathers and Stewart (1982).

Potassium

Sunflower shoots contained higher percentage of potassium both in the leaves and stem in the early stage at vegetative phase. The tissue concentration of this element declined at bud formation, improved with further growth recording a peak concentration at seed filling and again declined at harvest. Per cent potassium in the heads increased upto seed filling but declined at maturity. Robinson (1978) reported that the potassium content in the plant lowered with crop age upto flowering and increased again at harvest. But, Kalra and Tripathi (1980) and Seiler (1984) recorded a consistent decline till maturity. Hanumantha Rao and Vidya Sagar (1981) and Hocking and Steer (1983 b) also reported a decline in potassium content of leaves and stem with crop age. But, Mathers and Stewart (1982) recorded an increased concentration of potassium in the leaves with advance in age of the crop which declined at maturity. While, Llyod et al. (1980) observed that the potassium concentration of the index leaf (3rd most mature leaf from the top) increased to a maximum at the time when ray florets appeared and declined with further growth till harvest. Potassium per cent in the leaves and stem at different stages of crop growth were almost in equal proportion while the concentration was low in the capitulum.

At harvest heads contained a higher proportion each of nitrogen and phosphorus in the seeds while little remained in the disc. On the other hand most of the potassium was observed to have been retained by the discs while only a fraction of it was translocated to the seeds. It is also worth to place on record that nitrogen and phosphorus per cent in the seed while, potassium in the disc of the capitulum were more than in the shoots of sunflower plants. Reddy and Patil (1983) also reported that the phosphorus content in the sunflower seeds was more than in the plant.

b. Nutrient uptake

The uptake of mineral elements in different plant parts of sunflower broadly followed the pattern of dry matter accumulation as was also recorded by Rao (1974). Gachon (1972) reported that most of the nutrients are absorbed during the month before and the month after the beginning of flowering. But, the absorption and accumulation of ions in the plants is mostly dependent on a number of factors (lochwing, 1961; Coic et al., 1972 and Mathers and Stewart, 1982). Thus a great diversity in the findings concerning the nutrient concentration and their accumulation have been recorded in literature.

Nitrogen

The uptake of nitrogen in the leaves and stem increased with crop age upto flowering and declined towards maturity. Though the per cent nitrogen in the vegetative parts declined with crop age an increase in the uptake is obvious owing to the rapid accumulation of dry matter upto flowering stage. A net loss in the dry weight of leaves due to senescence and of stem due to translocation of nutrients in the reproductive structures after flowering in addition to the lower concentration were probably the reasons for a decline in the uptake in the later stages. The uptake of nitrogen in capitulum increased steadily till maturity. The greater proportion of dry matter accumulation probably over-compensated the sharp decline in per cent composition of this element leading to a greater uptake with progress in the development of the crop. During the first season, the uptake in capitulum declined at seed filling but improved again at maturity. This might be attributed to a greater reduction in the concentration of this element and a relatively less improvement in the dry matter accumulation of capitulum during the period from flowering to seed filling stage in this season. Increase in the uptake of nitrogen by the sunflower plants upto flowering beyond which the accumulation ceased practically confirms the earlier reports of Karatson and Boshkanyan (1966), Rao (1974) and Vrebalov (1974). Contrary to this, Kalra and Tripathi (1980) reported that the uptake continued till maturity. Increase in the uptake by leaves (Rao, 1974) as well as stems (Hocking and Steer, 1983 a) upto flowering and by capitulum (Rao, 1974) till harvest was also reported in the earlier studies. Mathers and Stewart (1982) observed that the uptake continued upto seed filling both in the leaves and stem. In the present study the uptake in stem ceased after flowering. This contradicts the observation of Rao (1974) who reported a consistent increase till harvest.

Throughout the crop growth, stems accumulated much lesser quantity of nitrogen than did leaves, despite the large contribution of stem to the plant dry matter from flowering stage. Hocking and Steer (1982) also pointed that the leaves are the main depository for nitrogen. However, at harvest the uptake by stem equalled that of leaves mainly because of a severe reduction in leaf contribution to the dry weight due to senescence. The uptake in the head was less than the leaves or stem at bud stage. Subsequently, it improved with greater uptake till harvest. At maturity 14.44, 17.75 and 67.81% of the total nitrogen accumulated in the shoot was in leaves, stem and head respectively during summer, 1983. The contribution during summer 1984 was 14.30, 13.52 and 72.18% while in kharif it was 20.08, 18.72 and 61.20% respectively. Mathers and Stewart (1982) reported that the heads contained about 40% of the total nitrogen found in the plants at maturity. Hocking and Steer (1983 a) reported that the leaves had accumulated nearly 14.00% of the plant's nitrogen at maturity.

Phosphorus

The uptake of phosphorus by the leaves and stem increased with crop age, reached the peak at flowering in the summer seasons and at seed filling in kharif. The uptake in capitulum rose to a maximum at maturity. Due to the low concentration of phosphorus because of its very low requirement the uptake pattern was mostly governed by the dry matter production. Plant's uptake of phosphorus till flowering was also reported by Karatson and Boshkanyan (1966) and Rao (1974). But Vrebalov (1974) and Hocking and Steer (1983 b) reported that the uptake of phosphorus by the plants occured even after full anthesis. While, Kalra and Tripathi (1980) observed that the accumulation of this element continued till harvest. The uptake of phosphorus in leaves and stem have been reported to increase upto bud stage (Rao, 1974) or seed filling (Mathers and Stewart, 1982) and decline in the later stages due to translocation in the heads.

Leaves had a greater contribution than the stem and reproductive structures in the uptake of phosphorus till the bud formation stage. But, the uptake in capitulum was most rapid from flowering stage increasing progressively till maturity. This indicates that there was a drain of phosphorus both in the leaves and stem due to its translocation in the capitulum. The contribution to total uptake in the shoot at maturity during summer, 1983 accounted for 6.66, 11.61 and 81.73% by leaves, stem and capitulum respectively. During summer 1984, the relative contribution was of the order of 5.93, 5.00 and 89.07% while in kharif it was 6.56, 19.28 and 74.16% respectively. Mathers and Stewart (1982) reported that the heads contained about 70% of the phosphorus in plant tops at maturity.

Potassium

The uptake of potassium in the leaves increased with crop upto seed filling stage both in the summer and kharif seasons during 1983 and upto flowering during summer 1984. The uptake in stem reached the peak values at seed filling in the three seasons. Potassium removed by the capitulum also increased with the development of the crop upto seed filling with little or no more addition thereafter as plants matured. Increase in the uptake of potassium by the plants with crop age till flowering/seed filling stage corroborates the findings of Karatson and Boshkanyan (1966) and Vrebalov (1974). Hocking and Steer (1983 b) also reported that the uptake of potassium in sunflower do not continue by about 10 days before the maturity of sunflower crop. While, Kalra and Tripathi (1980) reported that the uptake continued till harvest. Rao (1974) observed that the uptake in leaves increased upto flowering but continued further both in stem and head till maturity. Increased uptake of potassium in leaves and stem upto flowering stage was also observed by Mathers and Stewart (1982). But, they reported that some uptake occured again at maturity.

The relative contribution of potassium removed by different plant parts indicated that the leaf contribution was larger than the stem in the early stages. But, from flowering the uptake in stem was progressively more than in leaves. The capitulum had its greater share contributing to the total uptake later at maturity. The distribution of potassium in the leaves, stem and capitulum contributing to the total uptake in the shoot at maturity was of the order of 18.38, 39.59 and 42.03% during summer 1983. In kharif the respective share was 15.88, 46.20 and 37.92% while in summer 1984 it was 16.70, 35.19 and 48.11% respectively.

The effect of planting geometry with varied row widths and plant spacing of sunflower sown alone or intercropped with groundnut in general had no remarkable influence either on the nutrient composition or their uptake at different stages during the three seasons. This might be explicable in view of the dominant nature of the crop due to its prolific and vigorous growth habit that makes it withstand the varied competitive stresses exerted by the spatial configuration or the associated crops. The plant's ability in its rooting system to extract moisture and nutrients from below the normal rooting zone (Mathers and Stewart,1982 and Unger,1984) probably makes it an efficient crop in competing with the other species and also adjusting to the competition in the rhizosphere over a given nutritional area irrespective of the planting arrangement. Though the nutrients were removed by the associated groundnut crop, the effect on sunflower was not marked. This suggests that the sunflower probably extracted the nutrients from deeper layers and thus compensated its nutritional requirement as in the sole stand.

GROUNDNUT

General pattern of growth and development

Groundnut exhibits an indeterminate growth habit and the development of various plant parts may be influenced by a number of environmental factors. But, the pattern of growth and development was not influenced by the treatment effects during the three seasons, though the performance of groundnut was tremendously influenced by the planting system. Irrespective of the treatment effects plant growth was typically sigmoid in nature with the characteristic initial phase of plant height assuming the logarithmic growth followed by the linear and senescence phases. Plants increased in height throughout the growth period. But, the meristematic activity of the main axis was very rapid with 96% of the maximum height in the summer seasons and 99% of that in the *kharif* season being attained by about 90 days of sowing and slowed down later. Branching continued upto about 60 - 75 days and ceased in the later stages. But, the production of leaves followed a consistent increase in number till 105, 90 and 75 days during summer 1983, 1984 and *kharif* 1983 respectively. Leaves then declined towards harvest as the crop approached maturity due to senescence. Incessant rains in *kharif* caused earlier senescence while during summer, 1983 leaves were retained for a longer time upto 105 days since the emergence and maturity of the crop were delayed. Number of leaves is probably the most important character in groundnut production since it is positively correlated with the number of pods and pod yield per plant (Babu *et al*., 1985). Leaf area per plant increased upto 90 days in the summer seasons and upto 75 days in *kharif* followed by a decline towards harvest due to leaf loss. In the summer season during 1983, though the leaf number was maximum at 105 days, maximum area was attained by 90 days. Probably, the expansion of leaf laminae ceased beyond 90 days while the older leaves dropped off and thus lowered the leaf area per plant at 105 days sampling. The newly formed leaves which would obviously be very small might have added to the increase in number at this instant. Murthy *et al*. (1983) reported that the number of leaves and leaf expansion of the cultivar 'Kadiri-3' ceased beyond 90 days after sowing due to senescence of leaves. In an earlier study Bhan and Misra (1972) reported that the maximum growth of the plants was attained by 75 to 90 days after sowing in different cultivars.

Phytomass accumulation and distribution

Partitioning of the phytomass accumulation (Fig. 21) indicated that the dry weight of leaves increased with crop age till the maximum was attained in consonance with the production of leaves per plant and declined at maturity. Dry weight of stem increased upto harvest during summer 1983, while it increased upto 90 and 75 days during summer 1984 and kharif 1983 respectively with a subsequent decline towards maturity. The translocation of photosynthates into the reproductive sinks might have lowered the dry weight of stem during pod filling stage in these seasons. During summer, 1983, perhaps the supply of photosynthates was not limiting by the source as evinced by the prolonged retention of leaves. Gopalakrishnan and Veerannah (1968) observed that the dry weight of leaves and stem increased upto 60 days and remained almost static with little decline towards harvest. While, Williams (1979 c) reported that the stem growth which is perhaps the best indicator of assimilate availability continued very rapidly upto 12 weeks before it commenced a loss in weight towards maturity upto 18 weeks. The total vegetative mass of the groundnut shoots (Leaves and stem) increased with crop age till a fortnight prior to sowing during the summer seasons while it reached the peak much ahead by about 30 days before

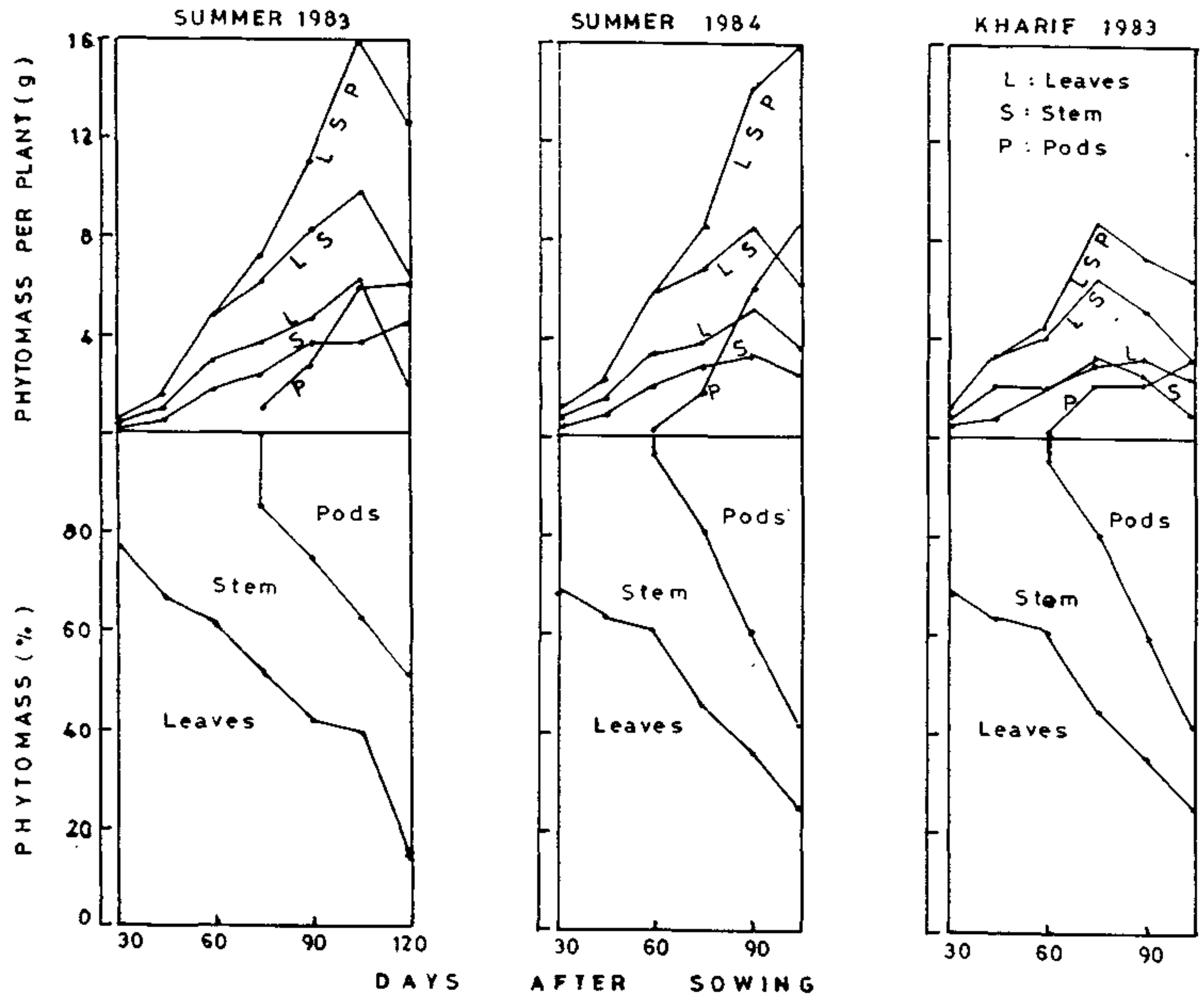

Fig: 21- ABSOLUTE AND RELATIVE PARTITION OF PHYTOMASS IN GROUNDNUT harvest in kharif. The dry weight of pods increased rapidly consequent with the formation and development of pods with increased availability of the assimilates till maturity. Phytomass accumulation per plant increased most rapidly with the addition of pod weight to the vegetative mass upto 105, 90 and 75 days during summer 1983, 1984 and kharif, 1983 respectively. However, loss in weight of the vegetative mass during the senile phase in the summer and kharif seasons during 1983 could not make up for the total weight even by the additional gain in mass of pods. These observations are in accordance with that of Enyi (1977) and Shelke and Khuspe (1980) who reported that the dry matter per plant declined at harvest after attaining the peak prior to maturity. But, Yayock (1979a) recorded a consistent rise in the dry weight per plant of groundnut till harvest.

The distribution of assimilates between the vegetative and reproductive components is of interest because distribution in favour of reproductive growth results in a greater rate of pod growth and therefore higher yields. The phytomass distribution pattern indicated that most of the metabolites produced in the early stages were present in the leaves while they were maximum in pods in the later stages. This observation falls in line with the findings of Enyi (1977). Edje (1980) also reported that the majority of the photosynthates were shunted into leaves and stems in the early stages but later into pods and stems. As growth progressed the assimilates were translocated to the stem and developing pods with the result that the per cent distribution of dry matter in leaves declined rapidly. The proportion of total dry matter diverted into the stem was less than in the leaves. But, this trend was reversed at harvest during summer 1983 and kharif 1983 because of the differences in the dry weight. The diversion of assimilates into the young developing pods increased very rapidly as growth advanced and thus had the greatest share of the total phytomass acquisition at harvest. Murthy *et al.* (1983) observed that the leaf and stem contributed almost equally upto 60 days while the stem contribution was more (60% and above) towards phytomass production later on till maturity.

Growth characteristics, yield components, pod and oil yield

Planting system exerted a tremendous influence on the performance of groundnut. The vegetative as well as reproductive growth was checked when groundnut was interplanted between the rows of sunflower. The morphophysiological traits recorded at 30 days sampling showed no marked variation due to planting system. Probably the interspecific competition in the first month of sowing was equal to the intra-specific competition since the growth and development of the sunflower crop was slow during this period. Later, sunflower grew rapidly, shaded the lower layers and smothered the intercropped groundnut more abundantly as the crops aged.

Irrespective of the planting system groundnut grew equally taller with no significant differences in the height of main axis measured at periodical intervals. The primary branches in intercrop system tended to grow in an upward direction with sparse leaf density and narrow canopy profile, against the observed lateral span in the sole crop of groundnut. As an intercrop component, groundnut experienced a considerable reduction in the number of branches per plant. The number of leaves, leaf area and flower production per plant were also severely affected due to the interspecific competition. The reduction in number of leaves and leaf area per plant of groundnut undersown with sunflower may perhaps obviously be attributed to the correspondingly lower number of branches per plant. Karve et al. (1984) reported that the shaded plants of groundnut generally produce fewer flowers and since the light transmitted through a layer of green leaves contains more photons of far red light than red, the plants grow tall and develop fewer branches. Shoot elongation is inhibited by white light and promoted by far red, whereas for branching the roles of white and far red light are reversed. In kharif, the number of leaves and leaf area per plant were less in the sole crop than in the intercrop system at harvest. Since leaf loss was comparatively more in the sole crop subjected to the direct splashes of rains while the intercrop component was guarded by the taller sunflower component, the pattern of leaf retention in the senile phase was reversed at maturity.

The potential of phytomass acquisition in the plant components was adversely affected by intercropping. Dry weight of leaves, stem, and pods were markedly reduced throughout the growth cycle of the crop. The ill-effects of intercropping on the vegetative growth were reflected on the development of reproductive organs. Sole crop of groundnut had a massive production of flowers and hence a large number of pegs were formed after fertilization. As the branches had a lateral spread, pegs had a greater chance of being closer to the ground and better able to penetrate the soil resulting in more number of pods per plant. Conversely, the intercropped groundnut developed only few flowers and those borne on the upper nodes of the erect growing branches were futile in that the pegs formed on these higher nodes could not penetrate the soil. The number of pods per plant were therefore very few in the intercrop system. Groundnut suffered not only due to the shading effect of sunflower but also due to the stiff competition encountered for the legitimate share of the nutrient elements from the labile pool. It is also not unlikely, that the sunflower secretes toxic substances that retards the growth of other plants around it (Rice, 1974; Riotte, 1975 and May and Misangu, 1980) although the toxic theory is generally discredited for practical application in field crop production (Robinson, 1978). In kharif, the interspecific competition was feable and hence the differences in the morpho-physiological characteristics due to planting system were not as much varying as in the summer seasons. The allelopathic effects of sunflower exudates even if present might have been evaded by the dilution effect due to continued rains. The inclement weather hindered the crop growth of both the species and thus limited the competition for nutrients. The poor canopy structure of the sunflower also mitigated to a large extent the shading effect on the intercrop.

The test weight of pods in intercrop system was significantly reduced in the three seasons while the reduction in shelling percentage was significant during *kharif*, 1983. The reduction in test weight of pods during the summer seasons is not an indication of plumpiness, since the shelling percentage indicated that the proportion of kernel weight to the shells was equal in both the systems of planting. The lower test weight, therefore, appears to be due to the limited pod size. But in *kharif*, it is likely that the translocation of assimilates into the reproductive sinks were also limited in addition to the small sized pods.

The cumulative effect of the yield components resulted in a significant yield variation due to planting system. Pod yield in intercrop system was reduced to about 43 and 60% of the yield realization from the sole crop during summer 1983 and 1984 respectively. The average reduction from the pooled analysis worked out to about 52%. This yield reduction reported here would be expected because of the competitive ability of sunflower due to its height. In *kharif*, groundnut in the intercrop system yielded about 85% of the produce from sole crop and yet showed no significant difference. The weak interspecific competition in intercrop system on one hand and the destruction of pods by the insect larvae in the sole crop on the other hand narrowed down the pod yield differences in this season. Pod yield reductions of groundnut to the extent of 62 - 72% recorded in recent attempts on intercropping of sunflower (Chandrasekhar and Morachan, 1979 b; Umapathy *et al.*, 1980 and Nikam *et al.*, 1984) are consistent with the results of this research. Sunflower was also reported to excercise a severe competition even when sown as an intercrop and the base crop of groundnut suffered due to highly significant reduction in the yield of pods (Vijay Kumar et al., 1973; Venkateswarlu et al., 1980 and Sindagi, 1982).

Sunflower smothered the vegetative growth of groundnut due to intense competition and reduced the haulm yield. This observation is in line with that of Nikam et al. (1984). While with minimum intraspecific competition, in sole crop, the groundnut plants were well nurtured and hence yielded higher quantity of pods and haulms per hectare.

Oil per cent in the sole crop was significantly more during summer 1983 while, the differences were not significant during the subsequent seasons. But, oil yield per hectare which is the product of kernel yield and oil per cent consistently recorded a significant improvement in the sole crop over the intercropped groundnut.

Planting method showed that the groundnut was not influenced by the narrow or wider row width treatments of sunflower/replaced groundnut. This indicated that varying the number of groundnut rows from two to three at a given planting density per unit area by widening the row width of sunflower in intercrop system or a similar manipulation in the sole crop of groundnut with the imposed intraspecific competition had no adverse effect. None of the biometric observations and yield attributes of groundnut were found to undergo a major change and hence the pod and haulm yield were also not influenced by the planting method. Shelling percentage alone was found to be significantly more in the narrow row treatment during *kharif*, 1983. Per cent oil in the kernels and oil yield per hectare were also unaffected.

Plant height, number of leaves and leaf area per plant were not influenced by the planting pattern. Equidistant row treatments favoured marginally better acquisition of phytomass in the plant parts. At harvest, number of pods and pod yield per plant were also numerically increased by the equidistant row treatments. The test weight was significantly reduced in the paired row treatments during summer, 1984 and *kharif* 1983 while the differences were not significant during summer, 1983. Pod and haulm yield of groundnut were reduced by the paired row treatments owing to reduced apparent nutritional area per plant. The yield differences were significant during summer 1984 and *kharif* 1983 since the expression of yield attributes were relatively more affected than in the summer season during 1983. Adjustment of plant spacing to 5 cm within the rows of groundnut in the paired row treatments reduced the shared area of the plants to 44 - 50% in comparison to 67 - 75% in the equidistant row treatments and thus increased the interplant competition. Variable response of groundnut to changed nutritional area by varying the row width and plant spacing configurations have also been reported by several workers (Cox and Reid, 1965; Naidu, 1968; Varisai Muhammad and Dorai Raj, 1974; Gopalaswamy *et al*., 1979 a; Chin Choy *et al*., 1982 and Kalra *et al*., 1984). At constant plant population, adjusting the row width and plant spacing variables with no change in the nutritional area per plant was reported to have no significant influence on the performance of groundnut in the earlier studies conducted at Tirupati and Parbhani (Venkateswarlu et al., 1980 and Bhosle, 1984). While, Elango and Nagarajan (1977) had observed considerable yield variation by a change in the crop geometry at a similar nutritional area per plant.

Neutro-periodism

a. Nutrient composition

The nutrient composition of vegetative parts indicated that there are two peaks of maximum requirement for nitrogen and potassium in groundnut. The tissue concentration of phosphorus followed a different trend.

The rise in concentration of nitrogen both in leaves and stem was much impressive at two critical stages corresponding with flowering (45 days) and pod development phases (90 days). Similar observations were also made by Putnamkar and Bathkal (1967) at Nagpur. Gopalakrishnan and Veerannah (1968) and Chahal et al. (1983) also observed that there are two peaks of nitrogen concentration. But, they noticed that the maximum tissue concentration in the vegetative parts was attained at seedling and mid-flowering stages of the crop. These reports also confirmed the present finding that the nitrogen per cent in the vegetative parts declined at maturity. Williams (1979 b) on the other hand showed that the nitrogen per cent in the leaves and stem declined steadily from 51 to 100 days after sowing and thereafter remained constant until maturity (180 days).

Potassium concentration followed a trend almost identical to nitrogen. The maximum concentration was coincident with flowering and pod formation (75 days) followed by a rapid decline in the later stages. This result concurs the findings of Soundara Rajan et al. (1984). But Gopala Krishnan and Veerannah (1968) as well as Chahal et al. (1983) reported that the concentration of potassium in leaves was maximum in the seedling stage. In stem it was reported to increase upto pre-flowering. The concentration in the leaves and stem then dropped off until harvest. A decline in the nitrogen concentration of vegetative parts from 45 to 75 days and that of potassium from 45 to 60 days prior to the second phase of peak requirement in the present study might presumably be due to the dilution effect and relatively lesser requirement than at other stages. With the initiation and development of pods these elements might have been translocated in larger amounts from the vegetative parts. Once the requirement of pods was met there was no further translocation.

The pattern of phosphorus absorption was different from nitrogen and potassium. The tissue concentration in leaves and stem increased with crop age upto 60 days when the pegs had penetrated the soil and initiation of pods began. Phosphorus per cent in the vegetative parts then dropped off rapidly in the later stages. This observation conflicts the report of Gopalakrishnan and Veerannah (1968). They observed that the phosphorus reached a higher concentration in the leaves much earlier in the pre-flowering stage. In stem it was more in the seedling stage, declined at pre-flowering, improved at mid-flowering and again declined at maturity. Chahal et al. (1983) found that the phosphorus percentage in leaves and stem was more during the seedling and pre-flowering stage respectively. They further observed that the concentration was lowered in the later stages but tended to increase at maturity. These conflicting results might be viewed in light of the edaphic factors and the genotypic and environmental variations (Virmani, 1973; Singh and Ahuja, 1985 and Nagaraj and Kailash Kumar, 1983) in which the experiments were conducted.

Initially, nitrogen in the pods increased from 75 to 90 days and attenuated towards maturity. The concentration of phosphorus and potassium on the other hand declined with the development and maturity of pods.

A comparison of the nutrient composition in the plant parts showed that the nitrogen percentage was more in leaves than in stem at different stages of crop growth. Once the reproductive growth commenced, pods had a higher concentration. But at maturity, per cent nitrogen in the pods was marginally less than in leaves. The tissue concentration of phosphorus did not show a marked variation in the different plant parts. Stem, generally had a higher per cent of potassium followed by leaves and pods. Gopalakrishnan and Veerannah (1968) recorded that the percentage nitrogen and phosphorus was high in the leaves and of potassium in the stem. Chahal et al. (1983) also reported that the potassium concentration was highest in the stem. But, Putnamkar and Bathkal (1968) on the contrary reported that the highest concentration of phosphorus was in the seed followed by leaves and stem. Potassium concentration was more in the leaves followed by seed and shoot. Padalia and Patel (1984) also observed that the highest percentage of nitrogen and phosphorus were in the order of pod, shoot and root.

The present findings clearly brought out that the absorption of phosphorus is rapid upto 60 days, while potassium is utilised till the pod formation (75 days) stage. Utilisation of nitrogen continued upto the pod development (90 days) stage and ceased before maturity.

The tissue concentration of nitrogen in different plant parts of groundnut was adversely affected in the intercrop system compared to the sole crop. Phosphorus and potassium concentration were however less affected. Competition for the extraction of soil nitrogen by groundnut and sunflower appears to have begun from the initial stages of crop establishment at 30 days and persisted throughout. Though the nutrient composition of groundnut was affected by the planting system, the neutro-periodism did not show a major change except that the second peak of nitrogen concentration in the leaves of intercropped groundnut was attained at 75 days compared to 90 days in the sole crop. This observation contradicts the earlier observations of Bhosle (1984). It was reported that the per cent nitrogen in different parts of groundnut was not affected when intercropped with sunflower.

A variation in the row width did not alter the tissue concentration of nitrogen, phosphorus or potassium in different plant parts. While, Chavan and Kalra (1983) reported that groundnut registered a higher percentage each of nitrogen, phosphorus and potassium in the wider row spacing of 45 cm than at 37.5 and 30 cm at a constant inter-row spacing of 15 cm. But Bhosle (1984) observed that the concentration of these elements in groundnut was not influenced either by the planting pattern or planting method. Nitrogen percentage in equidistant row treatment was marginally better than in the paired rows. The lower absorption of nitrogen in the paired row pattern might presumably be due to the increased interplant competition within the row as a consequence of decreased inter-row spacing of 5 cm in contrast to 10 cm in the equidistant row arrangement. But, the trend for phosphorus and potassium was not identical since these elements are less dynamic and get fixed in the soil.

b. Nutrient uptake

The nutrient uptake studies indicated that the leaves and stem removed nitrogen progressively upto the pod development stage (90 days) of the crop in the summer seasons. In kharif, leaf nitrogen increased upto the pod formation (75 days) stage, but the stem nitrogen continued to increase till the pods were in the developmental phase (90 days). The uptake of phosphorus was not considerable perhaps due to its very low requirement by groundnut as was also reported by Gopalakrishnan and Veerannah (1968). In leaves it increased consistently with crop age till the commencement of pod initiation (60 days) while in the stem it continued further but ceased at the pod formation stage (75 days). Potassium was removed in larger quantities with advance in crop age upto the pod formation stage at 75 days in the three seasons. Thus, concurdant with the findings of Nagaraj and Kailash Kumar (1983) the greater activity of these elements in the vegetative parts was observed during the reproductive growth phase corresponding with the initiation and development of pods (60-90 days).

With the commencement of reproductive growth, pods increased in the uptake of nitrogen and phosphorus upto 105 days during summer, 1983 and upto 90 days during summer, 1984. But, the uptake of potassium continued till maturity in the three seasons. In kharif pods removed higher amount of nitrogen upto 90 days, but the uptake of phosphorus and potassium declined with the commencement of pod formation (75 days) till maturity. The amount of nutrients removed from the soil is a function of per cent nutrient assimilation and the dry matter produced. But, the pattern of nutrients removed by different plant parts did not follow the trend in dry matter production. Sham Sunder and Vittal Rao (1980) observed that the uptake of nitrogen and potassium in groundnut increased upto 90 days but that of phosphorus upto 60 days and then declined at harvest. Nagaraj and Kailash Kumar (1983) reported that the nitrogen uptake was gradual in the first two months and increased abruptly in the third and fourth months. With a gradual activity in the first two months phosphorus reached the peak in the third month and slightly declined later on. They also reported that the potassium uptake increased gradually throughout except for a marginal decrease in the final growth phase.

The nutrient uptake in different plant parts of inter-cropped groundnut was much less than in the sole crop. Reduction in dry matter production and an adverse effect on the tissue concentration of nitrogen in groundnut sown in association with sunflower led to a grand reduction in the uptake of this element at different stages of growth. Though, the competitive effect for nutrient concentration of phosphorus and potassium was of a lesser magnitude, competition for growth and consequently the lower dry matter production of groundnut in intercrop system also led to a relatively lower uptake of these nutrients compared to the sole crop. Donald (1958) showed that if a component of crops in association absorbs or intercepts less than its share of a factor of production, e.g. light, it is likely to acquire a correspondingly small share of all other factors of production. The reduction in dry matter in the present experiment might be explained in terms of Donald's finding, i.e., the sunflower crop intercepted a greater share of the available light and this may have reduced groundnut demand for nutrients and consequently reduced its frame and growth.

Variation in row width had no considerable effect on the uptake of nitrogen, phosphorus and potassium in this study. But, Chavan and Kalra (1983) observed that the uptake of these elements was higher in closer spacing of 30 cm than at 37.5 and 45 cm.

Planting pattern indicated that the nutrient uptake was marginally better in the equidistant rows than in the paired row arrangement. Plants with closer inter-row spacings in the paired row pattern presumably encountered stiff competition. Increasing the interplant competition by decreasing the inter-row spacing (5 cm) thus affected the plant growth and nutrient composition in different plant parts. This resulted in a relatively lower uptake of the mineral elements compared to the equidistant row treatment given an inter-row spacing of 10 cm. Though these differences were not significant, they provide an indication of better nutritional absorption and uptake incident upon a change in the planting pattern from paired row to equidistant rows. Singh and Ahuja (1985) reported that the uptake of nitrogen and phosphorus was more at a plant spacing of 15 cm than at 10 or 20 cm with a constant row width of 45 cm.

Thus it is obvious that the groundnut crop suffered a greater loss of nutrient uptake particularly nitrogen when intercropped with sunflower. However, groundnut planted with varying row widths did not differ in the uptake of these nutrients. Though the equidistant row arrangement had an edge over the paired row pattern, the differences in uptake were not considerable.

INTERCROPPING

Planting system exerted a highly significant influence on the on-farm productivity of the economic end products in the three seasons. Intercropping groundnut in sunflower significantly improved the total productivity over each of the sole crops during summer 1984 and <u>kharif</u> 1983 but was on par with the sole crop of groundnut during summer, 1983. The total yield in intercrop system surpassed the sole crop yield of sunflower by 55, 84 and 28% during summer 1983, 1984 and kharif 1983 respectively. The yield advantage over sole crop of groundnut was however of a lesser magnitude in the summer seasons (7 and 13%) but was most promising with an excess yield of about 90% in the kharif season. The disparate growth habit of the two species could probably harness the resource availability and exploited the environment in a much better way when grown as companion crops than the individual components sown alone. The compatability of sunflower and groundnut resulting in higher productivity concurs the findings of several other research workers (Vijay Kumar et al., 1973; Singh and Singh, 1977; Kalawatia, 1979; Venkateswarlu et al., 1980; Hosmani, 1981; Ujjanaiah et al., 1981; Nagre, 1981; Sindagi, 1982 and Nikam et al., 1984). Improvement in the total productivity when sunflower was grown in association with the other leguminous and oilseed crops has also been reported in earlier studies (Singh and Singh, 1977; Desai and Goyal, 1980; Kachapur et al., 1980; Nagre, 1981 and Robinson, 1984). The competitive stress due to the intercropped groundnut had little or no adverse effect on sunflower in the summer seasons. The apparent yield advantage in intercrop system was therefore due to the additional yield of groundnut, while sunflower yielded as high as in the sole crop with no statistically significant differences. Among the sole crop comparisons which were highly significant, groundnut yielded 45 and 62% more than the seed yield of sunflower during summer, 1983 and 1984 respectively.

In kharif sunflower in the intercrop system yielded significantly less than the sole crop and yet the total productivity was overcompensated by the intercropped groundnut. Sole crop of groundnut, suffered heavy loss as much of the expected pod yield was obliterated due to the infestation of wireworms. This tilted the trend and the pod yield of groundnut was 32% less than the sole crop yield of sunflower. While, the pod yield of intercrop component being free from the pest disaster added much to the total productivity in the intercrop system.

Pearce and Gilliver (1978) argued that the above interpretation common in vogue with univariate analysis of intercropping yield data as if the two species grew independently of one another is open to objection. The two species grown in association may do well and impart a positive correlation or are in competition which tend to make the correlation negative, while it is not unlikely that these effects do cancel one another and show no correlation. Therefore the two variates of yield in intercrop system must be dealt with not separately but in conjunction and for this a bivariate analysis is required. They suggested that the results should be plotted on skew axes. Dear and Mead (1983) also pointed out that this method provides a useful means of displaying the results. The yield data analysed accordingly and displayed in Fig.13 indicated no correlation ($r = 0.01$) during summer 1983, while a positive correlation ($r = 0.35$) prevailed during summer 1984 possibly due to the relatively higher yields of both the species. In kharif the two species grew in stiff competition, yielded less and thus tended to make the correlation negative ($r = -0.38$). The residual variance matrix from the analysis allowed non-significance regions to be calculated for the total oilseed production due to intercropping. The circles which correspond to 5% non-significance regions did not intersect the lines corresponding to the sole crop yields of sunflower or groundnut in the summer seasons. This indicated that the total oilseed production was significantly greater than the sole crop yields. In the kharif season intercropping however was not significantly superior to the sole crop yield of sunflower as adjudged by the intersection of the non-significance region. These two treatments were on the other hand significantly superior to the sole crop of groundnut. The sole crop yields were not significantly different during summer 1983 while the pod yield of groundnut during summer 1984 was significantly greater than the seed yield of sunflower since the distance between the treatment lines (d^2) exceeded the calculated distance of 1.21 cm (Appendix III).

Oil yield comparison is no less important than the total seed yield from the intercrop system as it is in fact the ultimate end product that these two crops are grown for. If the aim is to achieve maximum oil production, then the seed yield evaluation of the system may not be a valid estimate. An important aspect of such a consideration is that the oil yield in groundnut is a function of per cent oil in the kernels that approximates about two-thirds the mass of pods. But, in sunflower it is a function of oil per cent and the weight of cypsela (kernels and shells). This is because that the variation in oil percentage and/or seed yield due to different treatments may impute larger deviations in the response trend quite distinctly different from the seed yield comparisons. Such a phenomenon has been well documented in the present investigations. Significantly higher quantity of oil was obtained by intercropping sunflower and groundnut than from the individual species grown alone in both the summer seasons. But, this trend was not in line with that of the seed yield. The production of total oilseeds due to intercropping was on a par with the pod yield of groundnut grown as a sole crop during summer 1983 while it was significantly superior during summer 1984. In kharif, the total oilseed production was significantly more than the sole crop yields either of sunflower or groundnut. While the oil yield trend indicated a differential response in that the production of oil from sole crop of sunflower was on par with that of the total oil yield from intercrop system. In earlier studies Venkateswarlu *et al*. (1980) and Nikam *et al*. (1984) recorded an improvement in the oil yield per hectare by intercropping sunflower and groundnut. Among the sole crop comparisons groundnut yielded significantly higher quantity of oil in the summer seasons, while, in kharif, sunflower outyielded the oil obtained from the sole crop of groundnut in analogy with the seed/pod yield trends. But, the magnitude of differences in oil yield narrowed down in contrast to the larger variations in seed/pod yields. The differential response for oil yield in kharif as against in the summer seasons is obviously due to the lower yields of groundnut.

Inclusion of two or three rows of groundnut as intercrops in the narrow and wider rows of sunflower were equally effective. Planting pattern, however, indicated that the equidistant rows of sunflower were distinctly superior to the paired rows for intercropping. The overall productivity of oilseeds as well as oil yield in intercrop system were substantially augmented by the equidistant row arrangement of sunflower. This phenomenal change in the productivity of the system might perhaps be attributed to the relatively poor performance of groundnut in the paired pattern due to the very close spacing of 5 cm which led to an overcrowding of plants within the row. It is possible that a more competitive stress might have occured between plants of the same species, although the effect of interspecific competition is another factor.

Recent literature has introduced several indices of combined yield to evaluate the advantages of intercropping over the sole crops. Among these, the concept of land equivalent ratio (LER) proposed by Willey and Osiru (1972) has largely been used in intercropping research. The principle for assessing yield advantages in intercropping, in which the LER is based was, however, first reported by Niqueux (1959). Land equivalent ratio is the sum of two partial land equivalent ratios (Reddy and Chetty, 1984) and has been defined as the sum of relative land areas required by sole crops to produce the same yields as obtained from intercropping (Ahmed and Rao, 1982). This expresses intercrop yields on a relative basis to the sole crops and provides a truer measure of the physiological advantage of intercropping (Willey, 1979).

The calculated LERs indicated that intercropping sunflower with groundnut was more productive than growing the individual components separately as could be gauged by the higher values which were greater than unity irrespective of the spatial arrangement in the three seasons (Fig.14 and Appendix V). The magnitude of intercropping advantage was more pronounced in the kharif than in the summer seasons. It is interesting to note that though the relative advantage of intercropping was less, the absolute yields were much higher in the summer seasons. This trend apparently gives credence to the belief that intercropping is less advantageous at higher level of productivity than at lower level. The partial land equivalent ratios (PLER) indicated that sunflower in the intercrop system produced more than 90% of the corresponding sole crop yields in most of the treatments during the summer seasons. The yield from intercrop component of groundnut was additive and ranged from 35 - 57% of the corresponding sole crop yields during summer 1983 and from 49 - 85% during summer 1984. It is therefore, obvious that the advantage of intercropping depended mostly on the yield of groundnut. The LERs were eventually augmented ranging from 1.31 to 1.55 during summer 1983 and from 1.26 to 1.79 during summer 1984. The mean LERs over the two years ranged from 1.28 to 1.67 for the different treatments. This implies that on an average 28 - 67% of more land would have been required for the sole crops to produce yields equivalent to those obtained from intercropping treatments. The higher PLERs for sunflower than the groundnut component indicate that it was a dominant crop in the mixture.

In kharif, the standardized sunflower yields were mostly less than 80% and ranged between 59 - 90% in different treatments. This is probably due to the significant yield reductions in the yield of sunflower owing to greater lodging losses and also possibly due to the relatively better competitive ability of groundnut in the intercrop system. The PLERs for groundnut on the other hand were generally higher than the sunflower and ranged between 0.67 to 1.00. This was mainly due to the severe pod yield reduction in the sole crop treatments of groundnut. The LER values ranged from 1.52 to 1.73, thus showing an yield advantage of 52 to 73%. Advantage of intercropping probably resulted from the complementary use of growth resources over time and space. The combined intercrop canopy or root system might have made greater and/or more efficient use of light, water and nutrients than the component sole crops. Nikam et al. (1984) also observed biological yield advantage of intercropping sunflower and groundnut with an LER of 1.14. However, Narwal and Malik (1985) reported that sunflower was not only most harmful to groundnut, but even the total yields were less than either of the sole crops with the result that the LER was only 0.79. The disadvantage of intercropping in this study appears probably due to the very close spacings of sunflower and the lower population (50% of the optimum) of groundnut component in the system.

Considering the socio-economic situations of a farming community, the economic values of the crop components and for several other reasons one of the crops in the intercrop system may be preferred more than the other. The objective may be to ascertain a fixed yield of the desired crop from a given land area, while the yield from the less important crop may be additive. But, the LER describes the land use giving equal weight to the individual crops in an intercropping system. It was on these grounds that the use of this index in intercrop research was criticized by Wijesinha et al. (1982). To overcome this difficulty Mead and Willey (1980) extended the concept to 'Effective land equivalent ratio' (ELER) in order to measure the biological efficiency of the system in which a desired yield proportion is set a priori. Later, Reddy and Chetty (1984) argued that the farmer may be more interested in achieving a fixed minimum yield of a particular crop in the intercrop system than in a predetermined ratio of yields. Therefore, they further modified this concept to the 'Staple land equivalent ratio' (SLER). The conceptual difference they referred to was that in ELER the yield advantage is assessed by keeping the harvested proportion of one of the crops (proportion of PLER of one of the crops to LER) at a constant value, while in the case of SLER the standardized yield of the crop is kept at a desired value. Riley (1985) concluded that the idea of stipulating a minimum required yield as for the SLER appears to be a more obvious and sensible requirement than the need to attain a particular ratio of yields as for the ELER. An attempt was therefore made to evaluate the SLERs for a range of desired yield levels of sunflower due to varying crop geometry treatments. The SLERs represented in Fig.15, which enable reading off the yield advantage indicated that intercropping groundnut between the paired rows of sunflower with a wider row width treatment was superior to the other spatial configurations at any desired yield level of sunflower in the summer seasons. Similar was the trend for mean performance over the two seasons. This treatment not only provided an standardized sunflower yield of 98% during summer 1983 and 94% during summer 1984, but also increased the biological efficiency of the system as could be seen by the maximum SLER values of 1.55 and 1.79 respectively. With still more desired yield level of sunflower the intercropping advantage was relatively less obvious. In the first year it was observed that if the standardized yield of sunflower was aimed at 99%, the wide-paired row treatment was equally good as the narrow-paired treatment with an SLER of 1.41. In the second year, narrow-paired rows were most effective with standardized sunflower yields upto 86%. But, with further increase in the desired yield level the SLER values declined. If the minimum requirement of sunflower was aimed at 89% the treatments with narrow-paired row arrangement and wide-equidistant rows were equally effective with an SLER of 1.41.

In <u>kharif</u>, narrow rows were better than the wider rows both in equidistant and paired pattern when the standardized yield requirement of sunflower was high. But, with lower standardized yields the wider rows were more beneficial. The wide-equidistant treatment was most advantageous upto 59% of the desired yield level of sunflower. But, with desired range increasing from 62 to 80%, the narrow-paired rows were the best and a maximum SLER of 1.73 was recorded with 80% standardized yield of sunflower. When the minimum requirement was aimed at 85%, the choice was either equidistant or paired pattern with narrow rows since the SLER from either of the treatments was 1.52. But, with more than 85% yield requirement of the staple crop the narrow-equidistant rows were preferable. The SLER diagrams thus provided a yard stick for choosing a package of agronomic practices to achieve a targetted standardized yield of sunflower as suggested by Reddy and Chetty (1984).

It is interesting to note that the total yield from intercropping system was much higher in the narrow-equidistant rows than in the wide-paired row pattern during summer 1983, while there were little differences during summer 1984. But, the SLERs indicated that the relative yield advantage was more in the wide-paired rows than in narrow-equidistant rows for a range of standardized yields of sunflower. This inverse trend is expected because the SLERs were assessed on the basis of sole crop yields grown in exactly the same way as in the intercrop system. Since, the sole crop yields were higher in the narrow-equidistant rows the relative advantages were less pronounced. It may thus be inferred that the yield advantages due to intercropping were more apparent in treatments with relatively lower yields of the sole crops in comparison.

The success of technological innovations are largely based on the total productivity and higher profits. Yet, the nutritional value of the crops with high quality balanced for energy requirements in human dietics is another concern which needs focus in developing any improved farm practice. The oilseed crops play an important role in human nutrition, since 15% of the dietary calories should be derived from the fats (Sen, 1979). This underlines that an improvement in the total nutritional value of the oilseed crops grown in association would assue a significance of practical importance. The present investigations have clearly brought out that intercropping of sunflower and groundnut significantly improved the total calorific equivalents of the system over the sole crops. The energy output of sunflower was little affected in intercrop system compared to the sole crop during summer 1983. However, the reduction was significant during summer 1984 and kharif 1983. Groundnut, as an intercrop component registered a tremendous decline compared to its sole stand in the summer seasons. While in kharif, the differences were not significant. Among the sole crops, the calorific equivalents of pod yields in groundnut were 32.83 and 40.40% more than from the seed yield of sunflower during summer 1983 and 1984 respectively. But, in kharif due to a grand loss in pod yield the calorific values were however 62.40% less than in sunflower. Indeed, these results thus indicate that intercropping is a beneficial system in exploring the dietic value of human nutrition through increased calorific equivalents than sowing the crops alone.

Besides the biological and competitive yield assessments, the economic evaluation of intercropping systems has focussed the research attention of many agronomists in the recent past. But, there has been no common way of evaluating the monetary advantage of the system. Gross return have mostly been the criteria, while the net returns have rarely been considered. Higher gross returns need not necessarily always imply a higher net return. The gross monetary values therefore do not really provide a true measure of the economic efficiency of the system. The highly fluctuating sale price of the economic end products and/or the variable cost of cultivation of the crop species warrant the net income considerations for the economic comparisons. The mean gross monetary returns were maximum in the intercrop system than in either of the sole crops during the three seasons (Appendix IV). But, the monetary value of interest to a farmer which is more realistic and a sound economic appraisal is the net profit. With higher expenditure on the cost of cultivation, the intercrop system fetched higher net profits of Rs 3490.50 and 5577.80 during summer 1983 and 1984 than the net profits of Rs 2998.95 and 3303.36 from the sole crop of sunflower. Sole crop of groundnut was most profitable (Rs 4114.40 and 5709.60) though the gross returns were less (Rs 8075.70 and 9520.35) than in the intercrop system (Rs 8647.60 and 10811.86) during both the years. A similar situation was encountered in an earlier study at Bangalore. The tall cultivar of sunflower (EC 68415) combined with groundnut in the intercrop system was less profitable than the sole crop of groundnut, while the gross returns were much higher. However, with a change in the genotype of sunflower to the short statured cultivar 'Morden', the intercrop system fetched higher gross as well as net returns than either of the sole crops (Sindagi, 1982). Venkateswarlu et al. (1980) also reported that intercropping of sunflower and groundnut was more profitable than the sole crop cultivation of groundnut. Opposing these findings, Umapathy et al. (1980) reported that intercropping of sunflower and groundnut was not remunerative as the net returns were less than the sole crops. A number of other workers (Singh and Singh, 1977; Kalawatia, 1979; Hosmani, 1981; Nagre, 1981 and Ujjanaiah *et al.*, 1981) have recorded maximum gross returns by inter-cropping sunflower and groundnut. However, the net profits due to variable costs have not been reported. Nikam *et al.* (1984) reported that the gross emoluments from the combined yield of sunflower and groundnut were less than the sole crop of groundnut but were substantially higher than the sole crop of sunflower.

In *kharif*, the sole crop of sunflower was most profitable with maximum net returns of Rs 1560.92. Though the gross emoluments were triggered more than in sunflower (Rs 3768.08) the intercrop system (Rs 4817.66) fetched a bear minimum profit of Rs 379.76. The pest incidence responsible for a grand reduction in pod yield of groundnut in sole crop led to a net loss of Rs 705.98.

Another economic consideration is the net profit per rupee investment rather than the net returns from the total investment per unit area. This is also very often the most desired objective for many farm situations. Higher investments may fetch maximum net returns. But, less investment over a unit area with lower net profits from another variable may at times be still more attractive due to the relatively higher per rupee returns. With limited economic capacity, the farmers may be tempted to adopt an agronomic variable that accrues maximum net profit per rupee investment. In the present context it would be seen that the sole crop of groundnut was most profitable with 37 and 73% higher net returns than the sole crop of sunflower during summer 1983 and 1984 respectively. But, the net profits gained from a rupee spent on the cultivation expenses of the two crops did not differ significantly. It is worth to place on record that the cultivation of sunflower was less expensive (Rs 2560.20) and less profitable (Rs 2998.95 and 3303.36) than the cost of cultivation (Rs 4298.61) as well as the net profit per hectare from groundnut (Rs 4114.40 and 5709.60) and yet the net returns per rupee investment were admirably similar. Another interesting feature is that the higher cost of cultivation (Rs 5438.00) fetched higher profits (Rs 3490.50 and 5577.80) from the intercrop system. But the net profits per rupee investment were significantly lowered to Re 0.64 and 1.02, while sunflower showed a net profit of Re 1.17 and 1.29 during the two years. In the kharif season, the per rupee returns followed a trend similar to the net profit per hectare. Sole crop of sunflower was most remunerative with a net profit of Re 0.71 per rupee investment. Sole crop of groundnut on the other hand incurred a loss of Re 0.20 per rupee investment. While with maximum expenditure on intercropping (Rs 4609.10) the profit per rupee investment was next to nil (Re 0.08).

Jain and Rao (1980) proposed the use of an index 'Relative net returns' (RNR) in intercrop research to assess the economic validity of combining the crops in relation to the sole crops. They reported that this index is independent of units and is more amenable to statistical analysis. The RNR indices followed an absolutely similar pattern as the net profit per hectare in the three seasons. The higher RNR values indicated that intercropping was superior to the sole crop of sunflower during the summer seasons. The lower values for groundnut implies that the sole crop was not less profitable than the intercrop system. The magnitude of intercropping advantage was highly significant over the sole crop of groundnut in the *kharif* season. This is primarily due to the monetary loss owing to pod yield reductions in the sole crop. The low RNR for sunflower shows its superior performance in fetching higher returns than the intercrop system. The RNR index thus provided a comparison of the intercrop system in relation to the sole crops by taking into account the variable cost of production and relative prices of each component. However, it did not provide the information for direct comparison as to which of the sole crops or the planting system was most superior. In the summer seasons sole crop of groundnut was most profitable while during *kharif* sunflower fetched the maximum net returns. But, this index, provided merely a comparative information as to whether or not intercropping was superior to the sole crops. Reddy and Chetty (1984) also reported that most intercropping indices are useful for understanding the behaviour of intercropping treatments, but have the disadvantage that they give no information on the absolute yield of the mixture or its components.

In intercropping research there are many items of interest in a single experiment, which involve yields from more than one crop and it is often difficult or impossible to identify a single criterion on which to base a statistical analysis, an evaluation or an interpretation as pointed out by Wijesinha et al. (1982). For instance different types of yield components for each of the crops involved in the intercropping system, monetary returns, net profits, total nutritive value in calories, land equivalent ratios, the staple land equivalent ratios and ofcourse the total oil yield in oilseed crops are some of the criteria. Therefore, the possible aspects of a planting system that varies with the goals of a farmer were considered in the present investigations. To sum up, the bivariate analysis of yield data has clearly brought out the significance of intercropping under high input system of oilseeds production in the summer seasons. Even if the objective is to increase the total production of oil, intercropping is a choice better than the sole crops. When sunflower is considered of prime importance in the staple diet because of its high physiological value of oil in human nutrition or in the farming system because it requires less capital and is less management intensive, the system still holds a promising practice. Sunflower performs equally well as in sole stand with least detriment and would further enhance the total production of oilseeds and oil. If the most important objective is to maximize the total productivity in a situation where land is limiting, intercropping of groundnut in paired rows of sunflower spaced 60 - 120 x 15 cm seems to be more advantageous with maximum LERs and yielding 94 - 98% of the sole crop requirement of sunflower. But, considering the total absolute yields it appears that the LERs of this treatment were inflated by the denominator in the PLERs of groundnut and that the different geometry of sunflower in intercrop system indicated no significant contrast. Irrespective of the planting geometry, the intercrop system thus provides a better land use efficiency in that a much larger area would have been required for the sole crops to attain similar yields as in intercrop system. With primary concern mainly vested in the monetary value of the crops intercropping appears to be beneficial with maximum gross returns. But since the monetary value of interest to a farmer would be the profit, sole crop of groundnut may be preferable as the economic net gains arrived at in the present investigations were not significantly different from the total profits in intercrop system. This option not only saves the extra cultivation expenses but also minimises the tedium of management problems in growing the two crops in association. Sole crop of sunflower on the other hand is least profitable. When the capital for investment is limited which really is the main constraint that most farmers are frought with, the alternative is to grow the sole crop of sunflower. With 40% less expenditure (Rs.2,560.20) than on groundnut (Rs.4,298.60) sunflower fetches equivalent profits on the basis of returns obtained over a rupee spent. The other advantage of growing sunflower is that except for the bird watch, it is more a care free crop yielding oil of better quality than groundnut, while, any possible expenditure due to the unforeseen natural calamities by the insect or disease incidence is also the least. Considering the criterian of returns per rupee investment intercropping is least efficient with minimum benefits while the operational costs are maximum.

In *kharif*, the total oilseed production was found to be significantly enhanced by intercropping. But, the bivariate analysis indicated that the sole crop yield of sunflower was not significantly different from the total oilseed production. The increased land use efficiency indicated by the upsurdly larger LERs was mainly due to the vitiated sole crop yields of groundnut. Though the total calorific equivalents were more, total oil yield was statistically similar to that of the oil yield from sole crop of sunflower. Considering the total crop values the gross returns were maximised due to intercropping. But, the net profits were maximum from the sole crop of sunflower and were minimum due to intercropping while groundnut incurred a loss. The profits based on per rupee investment were also maximum from sunflower, while intercropping showed no advantage. The limited results suggest that the cultivation of sunflower in the *kharif* season is the most potent and economically viable option. Though the total calorific equivalents were substantially enhanced due to intercropping it may appeal to a dietician, but it does not enter into the conciousness of a peasant farmer who is the one to be pursuaded. The earlier observations from the feasibility trials conducted over different locations in India also confirmed that sunflower performs better than groundnut in the *kharif* season (Maini, 1973).

PLANT POPULATION STUDIES

Sunflower sown as a sole crop or intercropped with groundnut presented an analogous behaviour to changes in planting density regulated by a systematic variation of row widths at a constant within the row spacing of 22.5 cm. Seed and oil yield per plant declined in a logarithmic order with natural base per unit increase in density. Pod yield and oil yield of groundnut per plant also indicated a similar relationship with density irrespective of the planting system. Seeds/pod or oil yield per plant was thus a function of planting density appearing as an exponent confirming the modelling approach developed by Liu Li et al. (1984) for sunflower. The quantitative relationship obtained by the fitted models indicated that the 'b' values were less than unity suggesting that the rate of decline per plant followed the exponential decay law (Little and Hills, 1978).

Yield per plant declined with increase in density owing to the consequent limitation of resource availability with a decrease in per plant nutritional area. While, the per hectare estimates improved probably due to the increased number of plants per unit area compensating for the per plant yield reductions. This was also true for the oil yield which is a function of seed/kernel yield and oil percentage. Since, the oil percentage was independent of the treatment effects, the relationship of oil yield to planting density was very much similar to yield.

The exponential models showed that the seed/pod and oil yield per hectare did not increase with increase in density beyond the estimated optimum for each treatment. This level of density measures the uppermost yield limit. A reduction in nutritional area per plant with an increase in density beyond the estimated optimum might confer an intra-specific competition with the resultant decline in compensatory response and eventually the per hectare productivity.

Seed or oil yield per hectare of sunflower in inter-crop system with narrow (T_2) or wider row (T_5) treatments were marginally less than in the respective sole crop treatments. Except for the narrow row treatment during summer 1984, the reduction in intercrop system relative to the respective sole crop widened sharply at higher densities (Figs.17 and 18). However, this effect was modest throughout the range of densities. This suggests the competitive nature of sun-flower by virtue of its prolific growth and more efficient uti-lisation of the available resources.

Seed and oil yield showed a marked increase associated with the addition of plants per hectare at the lower levels, but the curves plateaued with little differences at higher levels over a wide range of densities. Irrespective of the planting system the maximum yield estimates with optimum density hardly exceeded approximately 10% than that realised over a population of 75000 to 162134 plants ha^{-1} in the narrow row treatments. The wider row treatments also showed that the seed and oil yield were equivalent with densities ranging from 75000 to 107959 plants ha^{-1}.

Unlike sunflower, the performance of groundnut in intercrop system was strikingly different from the sole crop. Competition between disparate crops being very severe (interspecific competition) sunflower dominated and suppressed the groundnut crop althrough the range of densities. In summer seasons it suffered a tremendous yield reduction compared to the sole crop treatments grown over a similar nutritional area as in the intercrop system. The intercepts for pod and oil yield were much elevated in the sole crop than in the intercrop. The interspecific competition due to intercropping thus appears to have been severe even with the lower level of planting density. In addition, the higher values of the regression coefficients for groundnut in the intercrop system revealed that the interspecific competition further intensified at higher levels of plant population. It is also likely that the intra-specific competition between the plants of groundnut might have also set in at higher planting densities. It is therefore cogent that the response curves for sole and intercropped groundnut widened with increasing plant population. The deleterious effect of intercropping on pod and oil yield ha^{-1} was more severe in the narrow (T_2) than in the wider row (T_5) treatments possibly because of the lesser shared area (67%) than in the latter (75%). In the narrow row treatment during summer 1983 pod and oil yield declined with density while during summer 1984 the production curves increased initially and plateaued at higher levels. Probably the interspecific competition was more severe during summer 1983 and the intra-specific competition for resource availability among the groundnut plants also operated even at the lowest level of density combination which further intensified as the plant population increased. With 75% shared area in wider rows (T_5) the production curves increased with density and plateaued at the higher levels.

The yield maxima for pods in sole crop was attained with an optimum density of 2,32,775 and 3,16,032 plants ha^{-1}, while for oil yield 2,19,584 and 3,53,185 plants ha^{-1} during summer 1983 and 1984 respectively. In intercrop system with 67% shared area occupied by groundnut (T_2) the estimated optimum was limited to 1,19,401 and 2,07,774 plants ha^{-1} for pod yield while 1,18,491 and 2,15,723 plants ha^{-1} for oil yield in the respective seasons. Likewise, the optimum density of groundnut intercropped over 75% of the shared area in sunflower (T_5) was limited to 2,03,994 and 2,31,928 plants ha^{-1} for pod yield while 1,97,444 and 2,32,648 plants ha^{-1} for oil yield during summer 1983 and 1984 respectively. The sole crop optimum on the other hand was estimated at 2,67,074 and 2,89,976 plants ha^{-1} for pod yield while 2,55,904 and 2,79,239 plants ha^{-1} for oil yield in the respective years. It is thus apparent that the optimum density for maximum production was not only higher for the sole crop than the intercrop treatments but was also greater in groundnut with 75% shared area than with 67%. Magagula et al. (1979) also reported that the optimum plant populations for any species in intercropping are inherently different from those in monoculture.

In the *kharif* season heavy rains affected the crop growth and this led to poor yields of both the species whether intercropped or not. The competitive effects were thus largely reduced. At lower levels of plant population sunflower had little effect on groundnut since the intercepts for sole and intercropped groundnut did not vary markedly. The production curves with 67% shared area (T_2) for pod and oil yield ha^{-1} in intercrop system increased slowly with increase in plant population, but plateaued at higher levels. However, pod and oil yield in wider row treatment (T_5) did not show a marked reduction compared to the sole crop. The response curves increased with density and were parallel to the curves for sole crop. Thus it appears that the interspecific competition was feable in this treatment, while, the intra-specific competition did not exist. But, since the sole crop alone suffered due to the mild insect damage, the comparison of intercropped groundnut cannot be attributed mainly due to the competitive effects in this season.

Total oilseeds in intercrop system with narrow row treatment followed a linear response to planting density increasing from 17.39 to 24.42 q ha^{-1} during summer 1983 and from 18.52 to 35.00 q ha^{-1} during summer 1984. The total productivity was substantially more than the seed yield obtained from the sole crop of sunflower althrough the range of plant populations. The benefit due to intercropping was by way of the bonus yield of groundnut while sunflower yielded as high as in the sole crop with only a marginal reduction. Sunflower with a plant population of 35,467 plants ha^{-1} when intercropped with 70,735 plants ha^{-1} of groundnut yielded 70.32 and 100.65% more than the sole crop of sunflower during summer 1983 and 1984 respectively. Interestingly, the total yield at this level of density combination was equal to the maximum expected yield (17.39 q ha^{-1}) in sole crop of sunflower with a population of 1,23,152 plants ha^{-1} during summer 1983. But, in the second year the combined yield exceeded the maximum expected yield (15.62 q ha^{-1}) of sunflower in a solitary stand with an optimum density of 122067 plants ha^{-1} by 18.57%. Sole crop of groundnut yielded more than the sole crop of sunflower in both the summer seasons and even exceeded the total oilseed production due to intercropping at any level of comparable planting density in the first year. In the second year, the combined yield due to intercropping was more than the sole crop yield of groundnut and the advantage of increased productivity was more prominent with increasing plant population. In the kharif season intercropping was more advantageous than either of the sole crops. At the lowest level of density combination, the yield advantage (5.98 q ha^{-1}) over sole crops each of sunflower (2.90 q ha^{-1}) and groundnut (2.60 q ha^{-1}) was of the order of 106.20 and 130.00% respectively. The maximum expected yield (4.96 q ha^{-1}) in sole crop with an optimum population of 1,23,672 plants ha^{-1} of sunflower was also less by 20.56%. The maximum yield of 10.08 q ha^{-1} was achieved by way of intercropping sunflower at a population of 1,08,920 plants ha^{-1} with groundnut over 67% of its area. This accounted for 103.22 and 8.02% increase over the maximum expected yield of sunflower

(4.96 q ha^{-1}) and groundnut (9.33 q ha^{-1}) respectively.

Intercropping groundnut in sunflower with 75% shared area in the wider rows performed much better than with 67% shared area resulting in higher total productivity of the oilseed crops in the summer seasons. Among the sole crops, groundnut yielded more than sunflower. But, the overall productivity due to intercropping superceded the yields of either species grown in a solitary stand. With the minimum density combination of 23,616 and 70,735 plants ha^{-1} each of sunflower and groundnut, the total yields (17.95 and 18.97 q ha^{-1}) were 139.97 and 213.55% more than the sole crop yield of sunflower (7.48 and 6.05 q ha^{-1}) during summer 1983 and 1984 respectively. But, the yield advantage over sole crop of groundnut (15.80 and 15.22 q ha^{-1}) was to the extent only of 13.61 and 24.64%. The yield maxima of sunflower (14.72 and 13.10 q ha^{-1}) grown as a sole crop was also short of the total oilseed production obtained with the minimum density combination by 21.94 and 44.81%. Oilseed production due to intercropping increased with density of sunflower upto a maximum of 88,830 and 1,07,959 plants ha^{-1} during summer 1983 and 1984 registering a total seed yield of 31.07 and 36.60 q ha^{-1}. Intercropping was more beneficial than either of the sole crops since the total yields at these densities were 111.07 and 179.39% greater than the maximum expected yields from sunflower while 8.64 and 24.96% more than the pod yield of groundnut (28.60 and 29.29 q ha^{-1}). In <u>kharif</u> the total production of oilseeds (4.85 q ha^{-1}) by way of intercropping with minimum density combination surpassed the sole crop yield of sunflower (2.20 q ha^{-1}) and groundnut (3.05 q ha^{-1}) by 120.45 and 59.00% respectively. The maximum yield realised due to intercropping (11.67 q ha^{-1}) with a population of 1,07,959 plants ha^{-1} of sunflower intersown with groundnut over 75% of its area was 138.16 and 28.66% greater than the sole crop yield maxima of 4.90 and 9.07 q ha^{-1} respectively.

Oil yield per hectare was substantially augmented by intercropping than growing the two species individually as sole crops in the three seasons. Among the sole crops oil yield from groundnut was considerably more than from sunflower particularly at the higher levels of plant population in the summer seasons. Oil yield due to intercropping in narrow rows was slightly more than from the sole crop of groundnut at the extremely low and higher densities during summer 1983. In the second year total oil yield increased with plant population following a quadratic relationship and yielded more than the sole crops throughout the range of plant populations. Oil yield due to intercropping augmented at a much faster rate than in the sole crops during <u>kharif</u> 1983. A density of 35,467 plants ha^{-1} of sunflower intercropped with 70,735 plants ha^{-1} of groundnut yielded a total of 5.64 and 6.02 q ha^{-1} of oil during summer 1983 and 1984 respectively. While, the oil yield from sole crop of sunflower was only 3.63 and 3.46 q ha^{-1} and that of groundnut it was 5.15 and 4.05 q ha^{-1} during the respective seasons. In <u>kharif</u> oil yield due to intercropping (2.12 q ha^{-1}) was 78.33% more than from the sole crop of sunflower (1.20 q ha^{-1}) and 185.33%

more than that of groundnut (0.75 q ha^{-1}). The estimated maximum oil yield from sole crop of sunflower (6.12, 5.97 and 1.99 q ha^{-1}) during summer 1983, 1984 and <u>kharif</u> 1983 was approximately the same as that obtained due to intercropping with minimum level of plant populations. Oil yield due to intercropping increased with density and reached the maximum (8.28 q ha^{-1}) at the highest level of density combination i.e. 1,62,134 plants ha^{-1} of sunflower intercropped with 3,23,362 plants ha^{-1} of groundnut during summer 1983. This accounted for 35.29% more oil than the maximum expected from sole crop of sunflower (6.12 q ha^{-1}) but was equivocal to that obtained from sole crop of groundnut (8.12 q ha^{-1}). During summer 1984, the maximum oil yield (9.91 q ha^{-1}) realised with a population of 1,54,030 plants ha^{-1} of sunflower intercropped with groundnut was 66.00 and 8.90% in excess of the maximum from the sole crop of sunflower (5.97 q ha^{-1}) and groundnut (9.10 q ha^{-1}) respectively. In <u>kharif</u>, the maximum oil yield (3.52 q ha^{-1}) due to intercropping 1,08,669 plants ha^{-1} of sunflower with groundnut was 76.88 and 27.07% more than the maximum expected oil yield from sole crop of sunflower (1.99 q ha^{-1}) and groundnut (2.77 q ha^{-1}).

Intercropping in wider rows of sunflower yielded more oil than in the narrow rows owing to the greater nutritional area which resulted in higher productivity of seed/kernel, while the oil % did not vary markedly. Oil yield increased with increase in density from 5.33, 6.22 and 1.70 q ha^{-1} to a maximum of 9.75, 11.64 and 4.59 q ha^{-1} during summer 1983, 1984 and <u>kharif</u> 1983 and was greater than the oil yield obtained from either of the sole crops. At the lowest density of sunflower in association with groundnut the oil yield was 104.21, 178.92 and 93.19% more than the oil yield from sole crop of sunflower (2.61, 2.23 and 0.88 q ha^{-1}). The increase over sole crop of groundnut (4.71, 4.60 and 0.87 q ha^{-1}) was to the tune of 13.16, 35.22 and 95.40%. The maximum oil yield due to intercropping (9.57, 11.64 and 4.59 q ha^{-1}) with optimum densities of 81,932 plants ha^{-1} during summer, 1983 and 1,07,959 plants ha^{-1} both during summer 1984 and kharif, 1983 outyielded the maximum expected oil from the sole crop of sunflower (5.05, 4.76 and 1.97 q ha^{-1}) or groundnut (8.27, 8.73 and 2.50 q ha^{-1}).

The following inferences may be deduced from an overview of the experimental findings :

Sunflower possesses a remarkable plasticity in its response to adjust over a range of planting densities across a population of 75 x 10^3 to 162 x 10^3 plants per hectare with corresponding row width variables ranging from 27.5 to 60 cm at a constant intra-row spacing of 22.5 cm. The crop also exhibits a plastic response with approximately similar yields to a change in planting geometry regulated both by inter and intra-row spacings at a given density of 74 x 10^3 plants per hectare. Planting density across the range and the crop geometry are thus not the critical variables to substantially influence the productivity either in sole or intercrop system. Sunflower is a strong competitor in that it suffer only modest reductions in seed/oil yield over a large range of extremely low (23×10^3) to higher densities (162×10^3 plants ha^{-1}) when intercropped with groundnut. The inter-row spaces in sunflower therefore can be efficiently utilised at any desired planting density over the range in obtaining additional yield from the intercrop component with no detrimental effect to itself.

Like sunflower, the pod and oil yield of groundnut followed an exponential response to increase in planting density both in sole and intercrop system. The performance of groundnut was considerably suppressed with proportionately larger reductions in pod/oil yield when intercropped with densities sharing 2/3 nutritional area of sunflower than with 3/4 shared area.

Intercropping groundnut in sunflower over 3/4 of its nutritional area maximised the total productivity of oilseeds and oil per hectare at any level of given density ranging from 35×10^3 to 162×10^3 plants per hectare of sunflower. The maximum potential of total oilseed production may be realised with a sunflower population of 88×10^3 to 100×10^3 plants per hectare intersown with groundnut.

The possible contrasts for the adoption of a planting system very much depends on the goals of a farmer. Intercropping of sunflower and groundnut under high input system in the summer seasons is a production oriented technology. The sytem enhances the productivity of total oilseeds and oil yield with increased gross monetary returns and higher total nutritional value. The improved land use efficiency irrespective of the spatial configurations that the sunflower plants are grown is another favourable attribute for intercropping. However, if the aim is to maximise the net profits the best alternative is to opt for groundnut. But, when capital invesltment is a limitation, cultivation of sunflower is the best choice as it accrues approximately similar net returns per rupee investment with a considerably less expenditure than on groundnut. In *kharif* intercropping is in no way advantageous than the sole crop of sunflower except that the gross returns and the total calorific equivalents are improved. Growing sunflower is therefore the best choice in the *kharif* season in view of the maximum profitability and net returns per rupee invested with minimum expenditure.

CHAPTER VI

SUMMARY

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SUMMARY

Two field experiments were conducted on the sandy loam soil at the students' Farm, Agricultural College, Rajendranagar in the summer seasons during 1983, 1984 and also during *kharif* 1983. One of the experiments was designed in a 3 x 2^2 factorial randomised blocks pattern with three replications to study the crop geometry of sunflower in sole/intercrop system and also to evaluate the possible benefits if any by intercropping with groundnut. There were twelve treatments with 3 factors viz; Planting system, method and pattern of sunflower each studied at 2 levels i.e. sole vs intercrop system, narrow (60 cm) vs wider (90 cm) rows and equidistant (60/90 cm) vs paired row pattern (40-80/60-120 cm). A planting density of 74 x 10^3 plants ha^{-1} was tested for each treatment at varying spatial configurations. Groundnut as an intercrop component was additive with 333 x 10^3 plants ha^{-1}. Sole crop treatments of groundnut were included for each treatment so that a comparison of the appropriate sole and intercropped plots treated alike would give information on how much benefit sunflower had derived from its legume companion. The second experiment aimed at optimising the planting density of sunflower in sole/intercrop system was conducted in a systematic fan design with six treatments run over four replications. The treatments comprised of 26 planting densities of sunflower ranging from 23616 to 107959 and 35467 to 162134 plants ha^{-1} of sunflower grown as a sole crop or intercropped with groundnut. Two sole crop treatments of groundnut treated alike as in intercrop system were also included.

The experimental findings emerging from these trials are as follows :

CROP GEOMETRY

SUNFLOWER

The general pattern of growth and development of the sunflower plants was not influenced by the planting geometry whether sown as a sole crop or intercropped with groundnut. The crop attained over 90% of its maximum height by about the flowering stage while growth further continued till maturity. The number of leaves and leaf area per plant increased with crop age upto flowering and declined thereafter till maturity. Dry weight of leaves and stem followed a like trend while the capitulum increased in weight from bud formation till harvest. Phytomass distribution was more in the leaves till bud formation and later stems accounted for a greater proportion. But at maturity, the capitulum alone accounted for about 50% of the total phytomass in the shoots.

The concentration of nitrogen in the leaves and stem declined with crop age till maturity while in the capitulum it increased till seed filling stage of the crop. Phosphorus per cent in the leaves increased till seed filling while in stem and capitulum upto flowering stage. There were two peaks of potassium concentration in the leaves and stem coinciding with the vegetative (30 days) and seed filling stages (75 days). In the capitulum it increased upto seed filling and declined in the later stages. The uptake of nitrogen by leaves and stem increased upto seed filling and declined at harvest while in capitulum it increased steadily till maturity. The uptake of potassium by leaves increased upto seed filling stage in the summer and *kharif* seasons during 1983 and upto flowering during summer 1984. Stems removed this element at a faster rate till seed filling stage in the three seasons. Nitrogen and phosphorus uptake in the capitulum attained the peak values at maturity. The uptake of potassium increased upto flowering in the summer seasons but further increased till maturity in the *kharif* season.

The results also indicated that the crop geometry treatments were of no major consideration in influencing the performance of sunflower. The sole crop in general had an edge over the intercrop system for various parameters. This was relatively more prominent in the *kharif* than in the summer seasons. When intercropped with groundnut the morpho-physiological parameters viz; plant height, number of leaves, leaf area per plant and the phytomass accumulation in leaves, stem and capitulum were marginally affected at different stages of crop growth. The yield components viz; capitulum diameter, thousand seed weight, number of seeds per plant and the yield *per se* were also slightly depressed. Oil % in the achenes and oil yield per plant followed a similar trend. The elemental composition and uptake of N, P and K by different plant parts were also marginally affected. At harvest, sunflower in intercrop system yielded (1306.14 and 1277.04 kg ha^{-1}) as high as in the sole crop (1389.79 and 1465.89 kg ha^{-1}) with only a marginal reduction of 6 and 13% during summer 1983 and 1984 respectively. But, in *kharif*, the sole crop yielded (940.55 kg ha^{-1}) significantly more than when intercropped (663.64 kg ha^{-1}). The oil yield per hectare similarly did not differ significantly due to sole (514.44 and 550.74 kg ha^{-1}) or intercrop system (489.97 and 475.18 kg ha^{-1}) in the summer seasons. In kharif the sole crop yielded significantly higher quantity of oil (363.88 kg ha^{-1}) than when intercropped (252.33 kg ha^{-1}) with groundnut.

GROUNDNUT

The performance of groundnut was markedly influenced by the planting system. But, the pattern of growth and development over the crop growth period was not influenced by the treatments. Plants increased in height throughout the growth period with the characteristic sigmoid nature. About 96 to 99% of the height was attained by 90 days. Most of the branches were produced by 30 days after sowing while branching further continued upto about 75 days and ceased practically thereafter. Number of leaves per plant and their dry weight increased with crop age upto 105, 90 and 75 days during summer 1983, 1984 and kharif 1983 respectively. Leaf area increased upto 90 days in the summer seasons and upto 105 days in kharif. Dry weight of stem increased upto 120, 90 and 75 days during the summer seasons of 1983, 1984 and kharif 1983 respectively. Pods increased in weight till harvest. The phytomass distribution curves indicated that most of the metabolites produced per plant were maximum in the leaves in the early stages but were maximum in pods in the later stages.

There were two peaks of nitrogen and potassium requirement by groundnut. The tissue concentration of nitrogen in the leaves and stem was maximum at 45 and 90 days while that of potassium at 45 and 75 days. The pattern of phosphorus absorption was different. It increased upto 60 days and then dropped off rapidly in the later stages. Nitrogen in the pods increased from 75 to 90 days while phosphorus and potassium declined till maturity. The uptake of nitrogen and phosphorus by the leaves and stem increased upto 90 days in the summer seasons. In kharif maximum uptake of nitrogen in the leaves was recorded at 75 days, while in stem it continued to increase upto 90 days. Phosphorus in the leaves increased upto 60 days and in stem upto 75 days. Potassium was removed in larger quantities upto 75 days. The activity of these elements in the vegetative parts was thus greater during the reproductive growth period corresponding with the initiation and development of pods (60 - 90 days) in the three seasons. The uptake of nitrogen and phosphorus by the pods increased upto 105 days during summer 1983 and upto 90 days during summer 1984. The uptake of potassium continued till maturity. In the kharif season pods removed nitrogen upto 90 days but the uptake of phosphorus and potassium declined consistently from pod formation till maturity.

The competitive effects of sunflower on the growth of groundnut were not marked at 30 days sampling. Though the differences in plant heignt were not substantial at different stages of crop growth the primary branches per plant were drastically reduced and they tended to grow in an upward direction with considerably less number of leaves and flowers when intercropped in sunflower. The phytomass of leaves, stem or pods per plant was severely reduced by intercropping. The concentration and uptake of nitrogen, phosphorus and potassium by the leaves, stem and pods were much higher in the sole crop althrough the crop growth.

The number of pegs and pods per plant were also substantially more in the sole crop than in intercropped groundnut. The adverse effect on the performance of groundnut in intercrop system during the *kharif* season was relatively less severe than in the summer seasons. At harvest, hundred pods in the intercrop component weighed significantly less in the three seasons while the reduction in shelling % was significant only in the *kharif* season. The production per hectare (855.76 and 1422.98 kg ha^{-1}) was significantly reduced to 43 and 60% of the sole crop yield (2018.93 and 2380.90 kg ha^{-1}) during summer 1983 and 1984 respectively. In *kharif* the sole crop was severely damaged by the pod feeding insects - 'The wireworms' and yet it registered 15% higher yield (633.75 kg ha^{-1}) than the intercrop component (540.77 kg ha^{-1}) but did not differ significantly. The yield of haulms was however, significantly reduced due to intercropping in the three seasons. Oil % in the kernels was significantly lowered only during summer 1983. But, the reduction in oil yield per hectare (255.31, 422.73 and 131.24 kg ha^{-1}) was significant compared to the sole crop (647.34, 739.68 and 161.45 kg ha^{-1}) in the summer seasons and in *kharif* as well.

The planting pattern treatments did not influence the plant height, number of branches, number of leaves or the leaf area per plant. But, the phytomass accumulation and the nutrient uptake in the plant parts in the equidistant row treatments had an edge over the paired row pattern. The paired row treatments reduced the test weight of pods and pod and haulm yield per hectare significantly during summer 1984 and *kharif* 1983. Oil % was not influenced while the oil yield per hectare was significantly enhanced in the equidistant row treatments in the three seasons.

INTERCROPPING

Intercropping of sunflower and groundnut was most productive both in terms of total oilseeds and oil yield irrespective of the crop geometry of sunflower. The total seed yield (2161.90, 2702.96 and 1204.42 kg ha^{-1}) was 55, 84 and 28% more than the seed yield of sunflower (1389.79, 1465.89 and 940.55 kg ha^{-1}) during summer 1983, 1984 and kharif 1983 respectively. The corresponding increase over sole crop of groundnut (2018.93, 2380.69 and 633.75 kg ha^{-1}) was of the order of 7, 13 and 90%. The bivariate analysis revealed that the total oilseed production was significantly superior to either of the sole crop components in the summer seasons. But in kharif, the yield from sole crop of sunflower was on par with the total productivity due to intercropping. Among the sole crops groundnut yield was on par with sunflower during summer 1983, significantly more during summer 1984 and significantly less during kharif 1983. The total oil yield was significantly enhanced (745.28 and 897.84 kg ha^{-1}) in the summer seasons while, the little improvement (383.57 kg ha^{-1}) during kharif was not significantly different from the sole crop of sunflower (363.88 kg ha^{-1}). The land use efficiency due to varying crop geometry ranged from 31 to 55% during summer 1983, from 26 - 79% during summer 1984 and from 52 - 73% during kharif 1983. The staple land equivalent ratios (SLER) demonstrated that irrespective of the planting geometry sunflower can fit well in intercrop system with groundnut as a staple crop with least sacrifice in pod/oil yield per hectare. The system also increased the total calorific equivalents as well as the gross value of the crops in the three seasons. Sole crop of groundnut was however most profitable in the summer seasons while sunflower fetched maximum net profit in the *kharif* season. But the returns per rupee investment from sunflower (Rs.1.17 and 1.29) with a lesser expenditure were not significantly different from groundnut (Re.0.96 and 1.33) in the summer seasons. In *kharif* the per rupee returns were maximum from sunflower (Re.0.71) while groundnut incurred a loss (Re.0.20) and the intercrop system was not profitable (Re.0.08). The relative net return indices (RNR) were 1.11, 1.41 and 0.70 over sunflower during summer 1983, 1984 and *kharif* 1983 respectively. The corresponding indices over groundnut were 0.97, 1.06 and 1.45.

PLANT POPULATION

The plant population studies indicated that the yield-density relationship of sunflower or groundnut was governed by the exponent function $Y = ab^x$. The yield per plant declined with increase in density while the per hectare estimates followed an increase. Initially, the yield per hectare of sunflower in sole/intercrop system increased with density at a faster rate upto about 75×10^3 plants ha^{-1}. The yield curves then plateaued upto a maximum of 162×10^3 plants ha^{-1}. This corresponds to a row width variation from 27.5 to 60 cm with an intra-row spacing of 22.5 cm. The reduction in seed/oil yield of sunflower was modest at any level of given density from as low as 23×10^3 to 162×10^3 plants ha^{-1} when intercropped with groundnut. Groundnut as an intercrop component registered a severe reduction both in pod and oil yield. The reduction was relatively more severe in groundnut intercropped over 2/3 shared area of sunflower than with 3/4. The total oilseeds and oil yield per hectare were much impressive yielding more than the sole crops althrough the range of plant populations when sunflower was intercropped with groundnut over 3/4 of its shared area in the three seasons. The total yield was maximised with an estimated optimum density of 88830, 107959 and 120140 plants ha^{-1} of sunflower during summer 1983, 1984 and *kharif* 1983 respectively.

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* Original not seen.

APPENDICES

Appendix I. Emergence count of sunflower and groundnut

Treatments	Sunflower			Groundnut		
	Summer 1983	Kharif 1983	Summer 1984	Summer 1983	Kharif 1983	Summer 1984
T_1	96.4	98.4	99.3	-	-	-
T_2	98.7	95.9	98.6	92.6	85.7	90.1
T_3	-	-	-	93.5	89.6	88.5
T_4	95.9	96.7	97.2	-	-	-
T_5	99.3	94.8	98.5	88.7	90.2	92.5
T_6	-	-	-	91.2	87.8	89.3
T_7	98.2	95.3	96.7	-	-	-
T_8	97.4	92.9	98.5	90.0	85.4	92.5
T_9	-	-	-	88.5	86.0	87.9
T_{10}	98.3	95.8	98.6	-	-	-
T_{11}	99.5	97.2	97.7	87.6	84.8	88.5
T_{12}	-	-	-	88.4	86.1	91.6

Appendix II. Cost of cultivation of sunflower and groundnut grown as sole crops and in intercrop system in the summer seasons

Item	Unit	Cost per Unit Rs	Sunflower		Groundnut		Intercrop system	
			Physical units	Value Rs	Physical units	Value Rs	Physical Units	Value Rs
Male	Days	8.00	40	320.00	62	496.00	67	536.00
Female	Days	5.00	185	925.00	305	1830.00	360	2160.00
Ploughing, tillering and harrowing with tractor	-	-	-	300.00	-	300.00	-	300.00
Seeds	Kg	6.00	10	60.00	125	750.00	60 + 125	810.00
Fertilizers	-	-	-	683.40	-	364.80	-	1048.20
Pesticides	ml	-	[illegible]	[illegible]	1050	184.80	1050	184.80
Irrigations	-	20	6	120.00	8	160.00	8	160.00
Land revenue	-	-	-	15.00	-	15.00	-	15.00
Marketing & transport	-	-	-	100.00	-	100.00	-	100.00
Interest on working capital @ 14%	-	-	-	36.80	-	98.00	-	124.00
Total		-	-	2560.20	-	4298.60	-	5438.00

In kharif, after deducting the expenditure incurred on irrigations during the summer seasons and the interest thereof, the cost of cultivation worked out to
Rs.2201.26 for Sunflower
Rs.3496.71 for Groundnut and
Rs.4609.10 for intercrop system.

The market rates for fertilizers and pesticides were
Rs. 5.31 per kg nitrogen (N) ; Rs.6.56 per kg phosphorus (P_2O_5) and Rs.2.56 per kg Potassium (K_2O)
Rs.176.00 per litre for Monocrotophos, Rogor or Metasystox

Appendix III. Transformed yield data of sunflower (Z_1) and groundnut (Z_2)

Treatment	Summer 1983		Summer 1984		Kharif 1983	
	Z_1	Z_2	Z_1	Z_2	Z_1	Z_2
Sole crop	6.14	6.52	6.86	5.97	8.55	5.41
Intercrop	5.77	2.77	10.09	6.03	6.29	4.61
d^2	14.23*		14.55*		6.94*	
$\frac{4eFc}{n(e-1)}$	1.21		1.21		1.21	

Appendix IV. Gross returns (Rs ha^{-1}) from sunflower and groundnut in sole and intercrop system

Treatment	Summer 1983	Summer 1984	Kharif 1983
SSNE	6018.88	6728.52	3676.28
SSNP	5215.24	6095.84	3723.32
SSWE	6015.00	5308.28	3884.68
SSWP	4987.44	5321.60	3764.00
GSNE	4797.76	12109.12	3106.56
GSNP	7736.68	6997.80	1971.00
GSWE	8242.24	11794.56	2795.84
GSWP	6526.16	7179.92	2266.60
INE	9203.68	13144.40	4935.12
INP	8457.60	9823.92	4832.16
IWE	8312.12	11115.60	5083.36
IWP	8617.00	11163.52	4420.00
Sole Sunflower	5559.14	5863.56	3762.08
Sole Groundnut	8075.70	9520.35	2535.00
Intercrop system	8647.60	10811.86	4817.66

Appendix V. The partial land equivalent ratios of sunflower and groundnut and the total land equivalent ratios due to intercropping as influenced by varying crop geometry

Treatment	Summer 1983			Summer 1984			Pooled (Summer 1983 & 1984)			Kharif 1983		
	PLER		LER	PLER		LER	PLER		LER	PLER		LER
	Ls	Lg		Ls	Lg		Ls	Lg		Ls	Lg	
NE	0.96	0.35	1.31	0.77	0.49	1.26	0.86	0.42	1.28	0.90	0.67	1.57
NP	0.99	0.42	1.41	0.86	0.66	1.52	0.92	0.54	1.46	0.80	0.93	1.73
WE	0.83	0.40	1.23	0.94	0.52	1.46	0.88	0.46	1.34	0.59	1.00	1.59
WP	0.98	0.57	1.55	0.94	0.85	1.79	0.96	0.71	1.67	0.66	0.86	1.52

VITA

I, **Shaik Mohammad** was born on August 8, 1952 to Smt.Sakeena Begum and Sri Shaik Ahmed in Hyderabad city, Andhra Pradesh, India. I married miss Afroze Jehan of Hyderabad on November 29, 1977 and we have two sons and one daughter. I obtained my B.Sc degree in Agriculture from Andhra Pradesh Agricultural University Rajendranagar (Hyderabad) in 1973 and was awarded my M.Sc degree in Agriculture (Agronomy) by the Marathwada Agricultural University, Parbhani (Maharashtra) in 1975. I served the Department of Agriculture and Agricultural University of Andhra Pradesh from 1975 to 1982 as Agricultural officer, Research Assistant and Assistant Research officer. Presently I am working as Assistant Agronomist, College Farm,Rajendranagar, since December 1983.

During 1982, I was awarded the senior fellowship of Indian council of Agricultural Research and was sponsored by the Andhra Pradesh Agricultural University Rajendranagar for higher education at the Agricultural College, Rajendranagar. I worked for my Ph.D degree in Agronomy on the **"Crop geometry studies in Sunflower in association with groundnut"**, under the guidance of Dr.K.Anand Reddy, Associate Director of Research (NARP) Jagtial. I am a life member of the Indian society of Agronomy, Indian Society of Oilseeds Research, Indian Society of Seed Technology and The Madras Agricultural Journal. I am co-author of nineteen publications and am serving the Executive Council for the Indian Society of Oilseeds Research as its Joint Secretary.