D I S C U S S I O N

D I S C U S S I O N

SUNFLOWER

Morphological behaviour

Length of root (Tables 2A, 3A and 4A)

During the initial phase of growth the roots attained maximum length in monsoon (11.42 cms) compared to winter and summer (9.5 cms and 9 cms respectively). In all the seasons the roots showed rapid elongation till the 30th day. After 105 days the maximum length (32.7 cms) was attained in winter compared to monsoon (25.17 cms) and summer (32.0 cms). Thus there was not much difference between monsoon and summer (under irrigated conditions). After 30 days the rate of growth of roots was reduced and this coincided with the cessation of rapid increase in top growth. Brouwer (1962) reported similar observation in general.

Treatmentwise the root growth was favoured most by $treatment_1$ (NPK + FYM). The root growth under $treatment_3$ (FYM alone) was the least (even less than control receiving no NPK fertilizer or FYM). Even though the differences are not statistically significant it would be interesting to explore this point further to find out why root growth was the lowest under F.Y.M.

Stem growth (height) (Tables 2A, 3A and 4A; Fig. 2B)

The maximum height was attained in summer (about 206 cms) followed by winter (about 173 cms) and monsoon (about 151 cms). All treatments showed the same pattern of growth seasonwise. $Treatment_1$ (NPK + FYM) gave the maximum height followed by $treatment_2$ (NPK), $treatment_3$ and control.

During monsoon major part of the height was attained by the 45th day and the growth curve became more or less a pleteau by the 60th day. The increase in height in winter continued for 75 days and the curve became flat only during the last phase (75th to 105th day) when the final reading was taken. The summer curve showing the increase in height was more to like curve for winter.The increase in height continued till almost the 90th day when the curve became flat.

When the results are statistically analysed for significance it is seen (Tables 8, 10 and 11) that between treatments there was significant difference in height between $treatment_1$ and control and between $treatments_1$ and $_3$ at 1% level in summer. During the other two seasons the treatments did not differ significantly.

It is noteworthy that even in summer $treatment_1$ (NPK +

TABLE 8 : TEST OF SIGNIFICANCE OF SEASONS

	Height of plant	Total Biomass	Weight of 1000 seeds	Seed oil content	No. of seeds per plant	Harvest Index	Seed output/ha.	Oil output/ha
NIGER								
Between								
S_1 and S_2	20.1216**	14.0081**	0.2037	6.0636**	6.3606**	1.2821	5.2107**	3.2847**
S_1 and S_3	3.5067**	4.9835**	0.9273	0.2441	1.3159	2.2943*	1.2855	1.6668
S_2 and S_3	15.5247**	9.5040**	0.93039	1.6233	4.4895**	7.3999**	3.4766**	2.130
SUNFLOWER								
Between								
S_1 and S_2	5.2214**	0.4628	0.9873	4.169**	0.06123	2.1152	0.8026	2.231*
S_1 and S_3	10.437**	2.0692	1.9056	12.5677**	0.0768	4.7280**	0.1015	5.9457**
S_2 and S_3	6.9161**	2.5385*	0.6983	7.1246**	0.5163	1.9399	0.0112	1.292

S_1 = Monsoon
S_2 = Winter
S_3 = Summer

* Significant at 5% level

** Significant at 1% level

FYM) did not differ significantly from $treatment_2$ (NPK alone). Seasons differ significantly as far as stem height is concerned, at 1% level.

The analysis of variance (Table 11) shows that treatments give differences in height at 5% level of significance.

According to Schuster and Boye (1971) higher temperatures and shorter photoperiod accelerate the stem growth of sunflower. Our results fall in line.

<u>Root/shoot length ratio</u> (Tables 2A, 3A and 4A)

The behaviour of sunflower is what would normally be expected; the ratio is high in the initial stage and it gradually decreases. By the 15th day the shoot catches up the root in growth in length and the root/shoot ratio becomes less than unity.

<u>Total leaf surface (upper)</u> cm^2 per plant

(Tables 2A, 3A and 4A; Fig. 2A)

As is obvious the total leaf surface for a plant depends on the number of leaves and total leaf surface of individual leaves. Leaf size is biggest in summer and smallest in winter, but the number of leaves per plant was highest in summer and lowest in monsoon. The net result was that the total leaf surface per plant was highest in summer followed by winter, it being the least in monsoon.

So far as the biomass is concerned the results are in line with the general relationship that greater the leaf surface higher is the amount of biomass but from agronomic point of view the summer and winter yields of seed were low though the total leaf surface per plant was higher in both seasons than in monsoon. Obviously the economically important component of biomass is influenced by many other factors like the temperature, type of fertilizer, photoperiod etc.

$Treatment_1$ (NPK + FYM) produced the biggest leaves in all seasons. It was followed in this respect by $treatment_2$ (NPK), $treatment_3$ (FYM) also gave increased total leaf surface compared to the control, but not as much as given by NPK.

Tsvetkova (1975) has noted that there was a definite seasonal variation in the total leaf area of sunflower. Cupina and Jacic (1972) have reported that fertilizers (especially nitrogen) increase the leaf surface in sunflower.

Functional behaviour

Total biomass (dry matter per plant)
(Tables 2B, 3B and 4B; Fig. 5B)

Maximum rates of increase were observed upto the 75th day in monsoon and in summer, but the fast rate of increase continued till the 90th day in winter.

The highest biomass (on 105th day) was observed in summer followed by winter and monsoon. Increased leaf area per plant in winter and summer must have increased the Net Assimilation Rate and that, in turn, must have resulted in increased yield of dry matter. Also, a combination of high temperature and radiation has been shown to enhance productivity (Blackman et al., 1955; Wilson, 1967).

The seed yield was however, not directly related to the total biomass.

In all seasons $treatment_1$ gave the highest biomass. In monsoon and winter $treatment_1$ did not give significantly higher biomass and the difference was significant at 5% only in summer (Table 10). $Treatment_2$ (NPK) yielded significantly higher than $treatment_3$ (FYM) in winter and summer but not in monsoon.

Seasonwise, differences in the yield of total dry matter were significant between winter and summer only at 5% level (Table 8).

There are many reports showing that mineral fertilizers or any other form of fertilizers will improve the vegetative growth of plants and thus result in increased biomass accumulation (Kinman, 1963; Bhattacharya and Dasgupta, 1976; Sarma, 1968; Martin and Leonard, 1967; Bhattacharya, 1972; Zubriski and Zimmerman, 1974; Massey, 1971; Soine, 1970; Swallers and Fiek, 1973).

Root/shoot (weight) ratio (Tables 2B, 3B and 4 B).

As in the case of root/shoot length ratio the values were higher in the beginning and then it gradually decreased showing that the photosynthate accumulation in the root was faster in the early stages of growth and then it became very slow. After the proper development of root, the growth of stem became faster. Winter gave the highest value and monsoon the lowest value. Treatmentwise there was no notable difference.

Chlorophyll content (Tables 2B, 3B and 4B)

The chlorophyll content in plants under different seasons and treatments did not show any remarkable difference. Maximum chlorophyll content (mg per gram fresh weight of leaves) was observed during 75th day in monsoon and 60th day in winter. There after the chlorophyll content gradually decreased. But there was no appreciable difference between the chlorophyll content in plants in winter during 60th day and 75th day. A point here is that a higher chlorophyll content was noticed when there was a tendency for a reduction in the number of leaves (from the bottom) due to senescence. Though there was

1971; Massey, 1971; Coic *et al.*, 1972; Tsurkan, 1973), and phosphorus (Jocic, 1973), have been reported to increase the seed yield of Sunflower.

<u>Seed output</u> tonnes/hectare (Tables 2B1,3B1 and 4B1; Fig. 3).

On an average the seed yield per hectare was highest in monsoon and lowest in summer. All the treatments resulted in an increase in the seed yield per hectare, and the increase was the maximum under $treatment_1$ and higher under $treatment_2$. Both these treatments involved NPK and it indicates that NPK is more effective than FYM in increasing the seed yield. Nevertheless, from the ecological stand point recurrent application of NPK will deteriorate the quality of soil. In monsoon the treatmentwise difference in seed yield was not significant (Table 10). In winter $treatment_1$(NPK + FYM) was significantly superior over other treatments and control, the difference between $treatments_2$ and $_3$ was insignificant and these two treatments were significant over control. In summer the differences between treatments and control were significant. There was no significant difference between seasons in affecting the seed yield per hectare (Table 8). In seed output on an area basis treatments were significant but not seasons (Table 11). Thus for better seed yield monsoon is the best season and irrigation coupled with the proper application of NPK and FYM can increase the net return.

<u>Seed oil content</u> (%) (Tables 2B1, 3B1 and 4B1; Fig. 3)

Seed oil content was maximum in monsoon (about 47%) and the lowest in summer (about 37%). The values in monsoon were significantly higher over winter and summer and that in winter was significantly higher over summer (Table 8). Treatmentwise the combined application of fertilizers did produce a notably better result and the application of FYM alone (T_3) produced slightly better result that NPK alone (T_2) did. The differences are however, very small and insignificant (Table 10).Analysis of variance shows that seasons but not treatments significantly affected this characteristic (Table 11).

Johnson and Jellum (1972) observed that the oil percentage decreased from early May to June plantings. The decline in the seed oil content was attributed to high temperatures, especially to higher night temperatures (Hoeppe, 1976). This could be the reason for having the lowest seed oil content in summer. Premsekhar (1973) found that seed oil content was high in winter. His results are quite different from ours in the sense that seed oil content was about 3% higher in monsoon than in winter. Nitrogen has been reported to reduce the seed oil content and to increase seed weight (Givase <u>et al</u>., 1975; Kordunyanu and Belkin, 1970 and Yadav and Mahespal, 1973). On the other hand, there are some reports that nitrogen if applied in proper dose and time did not result in reduction in seed oil content (D'yakov, 1971). An increase in seed oil content as a result of NPK application was reported by Bamdad (1972) and Galogezk (1968); and Vijay, et al. (1975) found no significant effect. This could probably be due to variations in soil conditions. The present results show that NPK has no significant effect in improving the seed oil content.

Oil output per hectare (tonnes/hectare)
(Tables 2B1,3B1,4B1)

Oil output per hectare was the highest in winter and the lowest in summer. The variations in seed output and seed oil content were responsible for bringing about the variations in oil output. On an average the oil output was the highest in monsoon. Oil output was found to be significantly affected by seasons as well as treatments (Table 11). All fertilizer treatments were found to favourably affect oil output on an area basis. The combined application (NPK + FYM) yielded the best results followed by $Treatment_2$ (NPK) and $Treatment_3$ (FYM).

The Harvest Index (Tables 2B1 3B1 and 4B1,Fig. 3)

Dry matter production may be considered to be a resultant of three processes, (a) production by photosynthesis (b) consumption by respiration and (c) reservation. Based on the opinions of Watson (1956), Tsuno and Fujise (1965), Humphries (1967) and Spence (1970) the essential ways of ensuring increase in the economic yield from plants may be summarised as :-

(1) Increasing the total yield of the plant (dry weight) while maintaining the same proportion of economic yield, and

(2) increasing the harvest index i.e. the proportion of economic yield to whole plant yield.

The harvest index in the present study gave the highest value in monsoon and summer. It is already mentioned that maximum biomass production was in summer and the minimum in monsoon. The higher values of harvest index in monsoon, therefore, indicate that the quantity of assimilate partitioned to be stored in seed was more in monsoon and the least in summer. In winter as well as in summer the treatments did not (except T_3 in summer) increase the harvest index though they have succeeded in bringing about an increase in the total yield of the plant (Biomass). The proportion of the assimilate diverted to the growth of the economic part was less than in monsoon. Analysis of variance reveals that (Table 11) season is playing a significant role on harvest index of sunflower. In monsoon under treatments_2, 3 and Control, in winter under treatments_1 and $_3$ and in summer under treatment_3 only, plant biomass and seed biomass are found positively correlated

TABLE 14 : SUNFLOWER - CORRELATION BETWEEN VEGETATIVE BIOMASS AND SEED YIELD.

Treatment	Vegetative mass	Seed weight	r
MONSOON			
T_1	106.054 (16.113)	31.2147 (6.89)	-0.427
T_2	104.634 (24.782)	29.878 (6.555)	0.7171*
T_3	85.952 (10.801)	28.810 (9.201)	0.3164
T_4	75.591 (13.891)	25.149 (5.519)	0.7725*
WINTER			
T_1	116.960 (18.238)	35.780 (8.069)	0.1878
T_2	112.632) (12.7154)	27.070 (7.343)	-0.34005
T_3	97.798 (5.599)	22.950 (3.580)	0.61295*
T_4	76.601 (6.936)	17.090 (2.739)	-0.5780*
SUMMER			
T_1	152.567 (11.9896)	28.398 (5.121)	-0.8235*
T_2	137.224 (10.455)	26.962 (5.485)	-0.4780
T_3	118.799 (12.384)	26.264 (5.286)	0.16896
T_4	101.343 (10.277)	21.225 (5.841)	-0.3789

Figures in the parenthesis indicate the standard deviation.

* Significant at 5% level.

T_1 = Treatment 1 = Farm Yard Manure (FYM) + Mineral Fertilizers (NPK)

T_2 = Treatment 2 = Mineral Fertilizers (NPK)

T_3 = Treatment 3 = Farm Yard Manure (FYM)

T_4 = Treatment 4 = Control.

(Table 14). Mostly positive correlation is observed in monsoon and negative correlation in summer, suggesting that moisture and temperature are two important environmental factors affecting this aspect. Monsoon results were significantly higher over summer (Table 8) and only seasons and not treatments were significantly affecting the harvest index of sunflower (Table 11). Therefore, the success in sunflower farming depends more upon choosing the season than the fertilizer treatments.

Growth Analysis

NPP (Net Primary Productivity) $g.plant^{-1}.day^{-1}$

(Tables 2C, 3C and 4C; Fig. 6).

The NPP reaches its highest value in summer (about 4 for Treatments 1 and 2) around 60th day. This is true about all other treatments as they also reach their respective highest values of NPP around the 60th day.

The highest value of NPP in winter is also seen with $treatment_1$ and on the 60th day. In monsoon all treatments reach almost identical highest NPP on the 60th day, but the highest monsoon NPP (2.4) is way below those for winter and summer.

After 60th day the NPP begins to decline in all seasons and reaches almost the zero value by the 105th day.

The periods of high NPP (2 or above) are shorter (30 days for treatments 1 and 2; 20 days for treatment 3 and only 10 days for control in monsoon and 30 days for treatments 1 and 2, 25 days for treatment 3 and only 15 days for control in winter) than in summer when the high NPP period is much longer (50 days for treatment 1, 40 days for treatment 2 and 35 days for treatment 3 and control).

In winter and summer the NPP during this high NPP period reaches much higher values than in monsoon.

A noteworthy point about the high NPP periods is that in monsoon and winter the lengths of the period are comparable but the NPP attains much higher values (reaching nearly 4) in winter compared to monsoon (when the highest value of NPP is 2.4). Again in summer, not only the NPP values during this high NPP period are as high as those for winter but the period is much longer (35 to 50 days) compared to monsoon or winter. This would explain the differences in the yield of total dry matter per plant seasonwise (highest - 1.53 g - in summer, about the same - 151.7 g - in winter and only 124 g in monsoon).

Now NPP is a product of LAI and its function NAR. These parameters may now be examined.

LAI (Leaf Area Index) (Tables 2C, 3C and 4C; Fig. 6B)
Total upper leaf surface/ground area covered

All seasons give different patterns of change in LAI from 15th to 105th day. The patterns for monsoon and winter, however, present greater similarity any one of them compared to summer.

Highest LAI is attained in treatment 1 in all seasons, but the value for summer (4.7) is much higher than for winter (4.3) and monsoon (3.9).

Treatmentwise the order for LAI (from highest to lowest) is from treatment 1 to control except a minor fluctuation in monsoon (between 40th to 50th day) when treatment 3 slightly exceeds treatment 2. The yield of total biomass, however, exceeds for treatment 2 over treatment 3. This may be explained by the fact (which can be readily ascertained from Fig. 6B), that higher LAI is mained steadily over a longer period in treatment 2 than in treatment 3.

After 90th day the seasonal differences in the appearance of the crop are marked. In monsoon all treatments show heavy leaf shedding which is most marked in control. In contrast the winter and summer crops maintain greater LAI and appear greener than the monsoon crop. In summer only in control the plants lose leaves to give LAI lower than 0.5. In winter this is true about treatments 1 and 2 only, but in monsoon all treatments shed leaves to give LAI below 0.5.

NPP rose linearly with LAI. Similar observations have been made by Ashley (1965), Eik and Hanway (1966) and Hayashi (1966).

<u>LAR</u> (Leaf Area Ratio; Leaf area. dry wt.$^{-1}$ i.e. Leaf area per unit dry weight) cm^2/gm. (Tables 2C, 3C and 4C; and Fig. 5A).

All seasons show the same general trend - LAR decreasing from 15th to 105th day. The highest values for monsoon (approx. 200 to 250) and summer (approx. 195 to 210) were higher than for winter (145 to 165).

The graphs of changing LAR over time show rather uniform rate of change in winter; in monsoon and summer LAR decreases at a uniform fast rate upto the 60th day and 45th day respectively, but later the curve flattens showing more gradual decrease in LAR. LAR falls with age (Watson, 1952).

Blackman and Wilson (1951 a,& 1951 b) observed that LAR of sunflower was affected both by light intensity and temperature. Blackman <u>et al</u>. (1955), Wilson (1967) and Rajan <u>et al</u>. (1973) report that LAR was depressed by increasing light but augmented by raising temperature.

NAR (Net Assimilation Rate; mg. dry matter per sq.cm of leaf area per day)
(Tables 2C, 3C and 4C; Fig. 7).

The highest NAR (nearly 1.6) was attained in summer, for all treatments collectively and also individually.

In later part of the crop season (after 60th day) as far as NAR is concerned, treatment 3 (FYM) and control are superior or as good as treatment 2 (NPK) and 1 (NPK + FYM) and yet the yield of total biomass is the maximum for treatment 1 followed by treatments 2, 3 and control in decreasing order. This is obviously due to the factor of leaf surface area.This is clearly shown by table 15 which is compiled for winter, when the differences of NAR between treatments are much more marked than in other seasons.

Superior biomass yields in summer can be explained when we consider the facts (pl. see Fig. 7) that from 40th day to 55th day in summer all the treatments and control showed higher NAR than the highest attained in monsoon by any treatment. For treatments other than the control this period of higher NAR was even longer. In winter the highest NAR attained was about 1.2. In summer, again, all treatments (including control) show much higher NAR (than the highest for winter) for periods longer than 10 days (10 days for control and treatment 3; 15 days for treatment 2 and 25 days for treatment 1).

There are definite seasonal patterns of variations in NAR (Eze, 1973). NAR and LAR vary in opposite direction at many points of the life cycle (Figs. 5 and 7 in the present report; also, Eze, 1973).

NAR may have negative association with LAI (Varghese et al., 1976). This relationship is seen in Figs. 6 and 7 in the present investigation.

Changes in NAR are due to seasonal (environmental factors) (Gregory, 1926; Williams, 1946; Watson, 1947); NAR may vary at different periods in the life cycle also (Blackman et al., 1955; Blackman and Wilson, 1951 a). Fig. 7 clearly presents this observation.

RGR (Relative Growth Rate, rate of dry matter accumulation in proportion to the existing biomass (g. g^{-1} day^{-1}) (Tables 2C, 3C and 4C; Fig. 8).

A consequence of the sigmoid increase in dry weight with time is that the RGR declines continuously with time. The rate of fall may depend on temperature and light intensity (Bakhuyzen et al., 1937; Thorne, 1960; Friend et al., 1962). The data collected in the present investigation graphically presented in Fig. 8 fall in line with this observation. The rate of decline of RGR is steeper in monsoon and summer than in winter.

Niger (*Guizotia abyssinica* Cass.)

The economic importance of Niger in Indian agriculture has already been noted in introduction. The results of observations during the present investigation are summarised in tables and graphs and histograms as mentioned while discussing specific points below.

Morphological Behaviour of Niger

Length of Root (Tables 5A, 6A and 7A)

The root growth (in length) during the life cycle and in different seasons do not show any definite pattern.

Length of Stem (Height) (Tables 5A, 6A and 7A; Fig. 9B)

Maximum heights for the various treatments were attained in monsoon. The lowest heights were attained in winter and the summer heights were in between. The range for monsoon was about 90-95 cm; for winter 27-35 cm and for summer, 65-75 cm. Photoperiodic response may be responsible for these differences along with other climatic factors, Niger being a short-day plant.

In the matter of stem length, the various treatments did not differ significantly in monsoon; in winter all the treatments resulted in significantly longer stem compared to control. In summer the differences were significant only for treatment 3 over treatment 2 and control (Table 9).

Seasonwise, monsoon heights are significantly (at 1% level) greater than winter and summer and summer heights significantly over winter (Table 8).

Both the season and treatments affected the stem height significantly (Table 12).

According to Moughini quoted by Chavan (1961), Niger is a short day plant.

Root/shoot (length) ratio (Tables 5A, 6A and 7A)

The length of crop season varied for seasons; the winter and summer crops were ready for harvest and were harvested on 105th day; whereas the monsoon crop was harvested on 120th day. At the time of harvest the values of the root/shoot ratio were 0.496 for winter, 0.292 for summer and 0.193 for monsoon. This means that root development in monsoon was poorest compared to the stem. In absolute values, however, the root growths for the three seasons were comparable (16 cm for winter, 16 cm for summer and 18 cm for monsoon, in round figures).

Total number of leaves (Tables 5A, 6A, and 7A)

On 60th day the plants had the biggest number of leaves during monsoon (range 55 in control to 95 in treatment 1) followed by summer (20 for treatment 3 to 33 in treatment 1) and lowest number of leaves in winter the range was small (19 to 25), the control and treatment 1 having about 20 leaves each and the two other treatments having a few more leaves.

Total leaf area (upper surface) per plant (Fig. 14B)

The areas differ widely between seasons. Monsoon surface areas were the most extensive (max. 1630 sq. cm) compared to about 637 in summer and 235 in winter. A look at Fig. 14B will make it obvious that for long periods (ranging from 30 to 60 days) in monsoon the plants had leaf surface as big or bigger than the maximum for summer compared to winter both summer (for 20 to 40 days) and monsoon (for about 80 days) seasons had leaf surface as big or bigger than the maximum for winter over long periods. This will explain the final differences in yields between seasons.

Functional Behaviour

Total Biomass (Tables 5B, 6B and 7B; Fig. 9A)

In general the total biomass accumulation is highest for monsoon and lowest for winter. Seasonal differences are large, the averages for monsoon, winter and summer being (in round figures) 31, 4 and 19 gms per plant.

The treatments also differ with respect to total bio-mass. In monsoon all treatments yield significantly (at 1% level) higher than control and treatments 1 and 3 yield higher than treatment 2, but the differences are not statistically significant.

In winter all treatments yield low (the maximum (in treatment 1) yield of about 5 gm compares poorly with the lowest (22 gm for control) in monsoon. The treatments in winter, however, show differences among themselves; T_1 yields significantly higher than all other treatments, T_3 over T_2 and control and T_2 over control.

In summer, T_1 yielded significantly higher than all other treatments, T_2 and T_3 over control, there being no significant difference between T_2 and T_3 even though T_3 yields slightly higher than T_2.

The statistical details are given in Tables 8, 9 and 12.

<u>Root/shoot weight ratio</u> (Tables 5B, 6B and 7B)

The ratio increased from 0 to 45th day and then gradually decreased. At the time of final harvest (105th day in winter and summer and 120th day in monsoon) the treatments did not differ much in this ratio, treatment 1 showing only a slightly higher (0.073) ratio than other treatments (about 0.065). Seasonwise the highest average of 0.1 was observed in monsoon, the figures for winter and summer being lower and almost similar (0.045 and 0.054) respectively).

<u>Chlorophyll content</u> (Tables 5B, 6B and 7B)

The chlorophyll content in leaves increased gradually upto the 60th day; then it began to decrease. There were no marked differences between seasons or between treatments.

<u>Number of Heads/plant</u> (Tables $5B_1$, $6B_1$ and $7B_1$; Fig. 10)

Unlike sunflower (in which the oil yielding varieties have normally only one head) niger produces numerous heads per plant.

On an average about 60 heads per plant are produced in monsoon, only about 20 heads in winter and about 50 in summer. The treatments do not differ much during winter, but during monsoon and summer treatments 1 and 3 have more numerous heads than treatment 2 and control.

<u>Number of seeds per Head</u> (Tables $5B_1$, $6B_1$ and $7B_1$; Fig. 10).

Treatmentwise or seasonwise the differences are not noteworthy in this respect, though winter yields larger number of seeds per head than monsoon or summer.

<u>Number of seeds per plant</u> (Tables $5B_1$, $6B_1$ and $7B_1$; Fig. 10; statistical details in Tables 8, 9 and 12).

There was no significant difference between monsoon and summer, but both of them yielded significantly higher number of seeds than winter.

Treatmentwise there was not much difference amongst them in winter except that treatment 1 yielded significantly (at 5% level) higher number of seeds over control.

During monsoon treatments 1 and 3 yielded significantly higher number of seeds than treatment 2 and control (at 1% level). Treatment 2 yielded higher at 5% level over control.

In summer all treatments yielded significantly higher over control, but did not differ much amongst themselves except that treatment 3 was technically superior over treatment 2 statistically at 5% level.

<u>Test weight of 1000 seeds</u> (Tables $5B_1$, $6B_1$ and $7B_1$; Fig. 10. Statistical details in tables 8, 9 and 12).

Seasonal averages do not show significant differences, but treatments differ among themselves. In monsoon the three treatments show similar values of test weight of seeds and only treatment 1 is significantly higher than control at 5% level. In winter all treatments give significantly heavier seeds than control; treatment 1 gives slightly heavier seeds than treatments 2 and 3, but the differences are not statistically significant. Neither season nor treatment play significantly affect this characteristic (Table 12).

<u>Weight of seed per plant</u>

As in all treatments the plant populations were mained at the same uniform number, the final seed yields reflect weight of seed per plant for each season and treatment. The seed yield is given in tables $5B_1$, $6B_1$ and $7B_1$ and in Fig. 10.

<u>Seed output/hectare</u> (Tables $5B_1$, $6B_1$, and $7B_1$; Fig. 11. Statistical details in tables 8, 9 and 12).

Monsoon yields are higher than those for winter and summer; the winter yields are the lowest.

Treatmentwise, Treatment 1 (NPK + FYM) yields the highest in all seasons (309 kg in monsoon, 127.5 kg in winter and 247 kg in summer). The control yields are the lowest in all seasons. Treatment 3 (FYM) is always superior in yield to treatment 2 (NPK) but in winter and in summer the differences in yields of the two treatments are hardly noticeable. Only in monsoon Treatment 3 shows clear lead over Treatment 2, but, again, the differences are not statistically significant.

According to Bhosale and Patil (1977) and Patil and Tosh (1978) the seed yield in Niger can be doubled by fertilizer treatment. This is true even in the present investigation as can be readily seen from the presentation of data in Fig. 11, but it is questionable whether, under the present circumstances (when high yielding varieties of Niger are not available), it is economical to double the seed yield by fertilizer application. This point will be further elaborated later.

Table 13 gives data on correlations between total biomass and seed yield. All treatments in all seasons show negative correlations except treatment T_2 in monsoon (with $r = 0.43$ and T_1 ($r = 0.55$) and control ($r = 0.05$) in summer.

TABLE 13 : NIGER - CORRELATION BETWEEN VEGETATIVE BIOMASS AND SEED YIELD.

Treatment	Vegetative mass	Seed weight	r
MONSOON			
T_1	31.317 (2.0089)	3.711 (1.055)	-0.69193*
T_2	29.394 (2.899)	2.425 (0.335)	0.4312
T_3	31.389 (5.493)	3.206 (0.281)	-0.5183
T_4	19.997 (3.4574)	1.864 (0.432)	-0.9424*
WINTER			
T_1	3.576 (0.574)	1.531 (0.421)	-0.8992*
T_2	2.714 (0.388)	1.242 (0.243)	-0.46183
T_3	3.399 (0.440)	1.311 (0.259)	-0.2582
T_4	2.397 (0.322)	0.939 (0.248)	-0.5456
SUMMER			
T_1	22.436 (2.2243)	2.974 (1.005)	0.5459
T_2	15.722 (2.655)	2.428 (0.828)	-0.445
T_3	16.6963 (1.415)	2.510 (0.459)	-0.23188
T_4	11.150 (2.009)	1.284 (0.354)	0.05015

Figures in the parenthesis indicate the standard deviation.
* Significant at 5% level.

T_1 = Treatment 1 = Farm Yard Manure (FYM) + Mineral Fertilizers (NPK)
T_2 = Treatment 2 = Mineral Fertilizers (NPK)
T_3 = Treatment 3 = Farm Yard Manure (FYM)
T_4 = Treatment 4 = Control.

Thus it may be seen that only T_1 (NPK + FYM) in summer shows a noteworthy correlation (r more than 0.5) between total biomass and seed yield.

This calls for efforts to evolve varieties which can divert larger part of the total biomass to the compartment of seed yield if Niger is to become an important source of oil.

Harvest Index (Tables $5B_1$, $6B_1$ and $7B_1$; Fig. 11. Statistical details in tables 8, 9 and 12).

Winter gives the best harvest index (minimum 0.279 for Treatment 3 and maximum 0.315 for Treatment 2; control index being 0.382). The indices for monsoon and summer are low (0.078 to 0.138 minimum and maximum respectively).

Even though the harvest index for winter is much higher (more than double) than monsoon and summer, the poor winter yields result in poor final yield/hectare.

The results also show that fertilizer application is of no particular significance as far as harvest index is concerned.

Seed oil content (Tables $5B_1$, $6B_1$ and $7B_1$; Fig. 11. Statistical details in tables 8, 9 and 12).

In short neither season or the treatments have any significant bearing on this important parameter.

Statistically, though, in winter oil per cent is significantly higher than monsoon oil per cent (Winter : 42.1%; monsoon : 38.9%). The poor winter seed yields, however, would nullify this small difference in oil per cent in favour of winter. Differences in fertilizer input do not affect oil per cent significantly.

Oil output/hectare (Tables $5B_1$, $6B_1$ and $7B_1$)

In all seasons, Treatment 1 (NPK + FYM) gives the highest yield of oil in terms of kg/hectare. T_3 (F.Y.M.) comes next. Control yield is the lowest.

When we consider whether the increased seed or oil output of Treatment 1 over other treatments compensates for the additional expenditure involved, Treatment 1 cannot maintain its favourable position. This point is discussed in detail later.

Though the yield is poor, being a short duration oil yielding crop Niger deserves due attention. Higher density of plants per plot may be maintained and optimum fertilizer level determined for obtaining profitable yield.

Growth Analysis

NPP (Net Primary Productivity)

g dry matter per day per plant

(Tables 5C, 6C and 7C; Fig. 12A)

The NPP attains its highest rate around 60th day in all seasons and in all treatments.

The NPP in winter is very low in comparison to monsoon and summer. During the period between 50th day to 80th day all treatments produce at a higher rate than the highest attained by the control.

This observation may have important bearing on irrigation and fertilizer application.

T_3 (FYM) shows superior NPP than T_2 (NPK) in all seasons. This may reflect the beneficial effect of FYM on soil conditions. When NPK is added to FYM (i.e. in Treatment 1) the highest NPP is achieved but calculations on the basis of input and output in terms of economic harvest show that the gain is not always commensurate with additional input over treatments 2 and 3.

LAI (Leaf Area Index)

Total upper leaf surface/ground area covered.

(Tables 5C, 6C, and 7C; Fig. 13B).

The patterns of changes in LAI seasonwise and treatment-wise follow those of NPP.

A noteworthy point is that the LAI of Treatment 3 (FYM) is always above that of Treatment 2 (NPK) and often reaches the value of LAI for Treatment 1 (NPK + FYM) at corresponding growth period.

<u>LAR</u> (Leaf Area Ratio; Leaf Area per unit dry weight)

(Tables 5C, 6C and 7C; Fig. 12B).

In the period of first 30 days the LAR of Treatment 2 (NPK) exceeds that of any other treatment in monsoon and summer. In these seasons from about 45th day onwards the differences between treatments (with regard to LAR) are not large. Also, in summer LAR's for Treatments 1 and 2 have almost the same value.

The behaviour of LAR in winter gives a different pattern compared to monsoon and summer. The treatments change their relative ranks often before behaving almost uniformly from 75th day onwards.

<u>NAR</u> (Net Assimilation Rate; mg. dry matter per sq. cm of leaf area per day).

(Tables 5C, 6C and 7C; Fig. 13A)

NAR is much higher in summer most of the time during the crop period than in monsoon and winter. The patterns of change are different seasonwise and treatmentwise especially in monsoon and winter. Treatments closely resemble one another in the later part of the life cycle (from 105th day to 120th day in monsoon and from 75th day to 105th day in winter), and in the middle period (45th day to 75th day) in summer. This is particularly true of treatments 2 and 3 and control in summer.

In other respects Niger behaves like Sunflower with respect to NAR.

<u>RGR</u> (Relative Growth Rate; rate of dry matter accumulation in proportion to the existing biomass). (Tables 5C, 6C and 7C; Fig. 14A).

The behaviour patterns of Niger with respect to RGR seasonwise and treatmentwise resemble those of Sunflower except that the differences between treatments in winter in Niger are smaller than in case of Sunflower; in Niger, in all seasons, all the treatments tend to attain the same RGR from 60th to 75th day onwards.

Agronomical and Economical considerations

So far the data have been analysed and discussed from a rather academic points of view of a physiologist and of an ecologist. Such basic information is essential for planning.

There is acute shortage of edible oils. Sunflower is a proved source of edible oil. At present niger oil is used mostly as an industrial harmless raw material or as a harmless adulterant added to sesame oil.

The data may now be analysed from the point of view of an agronomist and that of a farmer.

Agronomic considerations and Farmers' view point

An agronomist would be interested in increasing the economically important component of the net increase in biomass; of seed and oil in case of oil seed crops.

The discussion here has certain limitations. It would apply to Sunflower crop grown in Baroda climatic conditions on a black loamy soil. The variety employed was EC. 68415. Seeds were obtained from ICAR Regional Research Station, Coimbatore, and was grown under irrigated conditions.
The Niger variety employed was N-35 obtained from J.N.K.V.V. Jabalpur.

Sunflower (Tables 16 and 17)

If it is assumed that the crop can be grown under field conditions with enough rain fall one may expect 2100 kg of seed per hectare without applying FYM or NPK fertilizers. Quite possibly such a cropping system cannot go on indefinitely as a time would come when application of fertilizer may become necessary.

In monsoon, application of FYM (Treatment 2) resulted in an increase of 200 kg of seed yield. At Rs. 400/- per quintal the increased yield would fetch Rs. 800/- but at an expense of Rs. 700 (the cost of 10 cartloads of FYM).

If NPK fertilizer is used in place of FYM at rates used in this investigation (costing about Rs. 700; same as the cost of FYM) the expected increase in seed yield is of the order of 400 kg which means that input worth Rs. 700 in this case may result in an additional revenue of Rs. 1600; the profits would decrease to the extent of other expenses not considered here. Again the long term effect of using chemical fertilizers without FYM has to be considered; alternatively FYM may be periodically applied the cost of which would reduce profits. NPK + FYM with irrigation (Treatment 1) would result in an additional increase in seed yield worth Rs. 2000 against an input worth Rs. 1400 over control if other costs are not considered.

Thus agronomic practice like Treatment 1 should be attractive to farmers but the farmers would need an assured supply of fertilizers and FYM at reasonable rates.

Sunflower as a winter crop would be still more profitable, the additional output of Rs. 2000 against an input of Rs. 1400 for Treatment 3 is not bad; the profits would go still higher (additional Rs. 3600/hectare over control) if NPK fertilizers are used and 6400 against an input worth Rs. 2100 (Treatment 1) would be quite attractive.

The summer crop of Sunflower does not appear remunerative, the output against input being Rs. 1600 against Rs. 700 (Treatment 1); Rs. 1600 against Rs. 1400 (Treatment 2) and Rs. 2400 against Rs. 2100 (Treatment 3). Here we see that fertilizer and FYM application does give increased seed yields but the farmer may not find the practice remunerative as besides fertilizers and irrigations he has to spend on many other things like pest control.

If it is desired to encourage Sunflower farming as a summer crop to serve as an additional source of edible oils, it will be necessary to evolve high yielding varieties for summer cropping; also it may be necessary to provide power and fertilizers to the farmers at subsidized rates.

Now so far only the seed yield is considered as the farmer would naturally be concerned with getting a higher seed yield. But from the view-point of the national requirement of increased supply of edible oils, the output in terms of oil would be more profitable than when seed output is considered (Table 17). Here one can see that by adding an input worth Rs. 700 (Treatment 3), Rs. 1400 (Treatment 2) and Rs. 2100 (Treatment 1) over control the increase in output (when counted in terms of increased oil output at the rate of Rs. 1300/- per quintal) would be worth more than the seed output.

Thus improved farming technique (using irrigation, NPK, FYM etc.) would result in increasing the oil output but a farmer may not appreciate this as he has to sell his produce in form of seed at a price fixed for seed. The Government and the trade (who would be directly benefitted by the increased oil output) should help and encourage farmers to employ improved agronomic practices even by offering him subsidies if necessary as, ultimately, it would benefit the nation and the trade.

As seen in Tables 16 and 17 winter crop would give the highest return; the summer and monsoon crops may also turn out profitable but not as much as the winter crop.

Niger (Tables 18 and 19)

With the varieties now available it appears that employing irrigation and FYM and/or fertilizers is not remunerative to the farmer even though, in percentage, the yields (which are very low to start with) can be appreciably increased; for example in Niger as a monsoon crop by employing treatment 1 at an additional cost (over control) of Rs. 1400 the seed yield can be doubled (from 155 kg to 309 kg) but the additional seed yield would fetch only Rs. 616 against the input of Rs. 1400. This shows, that unless better higher yielding varieties of Niger are evolved it will not prove profitable for farmers to grow niger whenever it is possible for them to grow other more profitable crops. This explains why at present niger cultivation is mostly and usually confined to poor soils and as a hedge crop.

Niger can be a good source of industrially useful oil provided higher yielding varieties are evolved.

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