I N T R O D U C T I O N

INTRODUCTION

Vegetable oils and fats play an important role in the Indian economy. With a current production of about twelve million tonnes, valued at about five thousand crores of rupees, oil seeds form the second largest agricultural product in quantity and value.

Major oil crops such as groundnut, sesame (sesamum), rape seed, linseed, coconut etc., are cultivated in India in about sixteen and a half million hectares (Kumar et al., 1979). Despite the large area of cultivation the yield of oil seeds in India is the lowest in the world (736 kg/hectare, compared to a record of 1,615.38 kg per hectare in Nigeria). The shortage of oil seeds in India is such that the per capita consumption has declined from 3.4 kg/year in 1958-'59 to 3 kg in 1974-75, whereas the ICMR recommendation is 20 kg/year (T.O.I. year Book, 1978). The situation is further aggravated by the frequent fluctuations in the already increasing market price of vegetable oils especially that of edible oils, the impact of which on the economically backward class of population is spectacular and is of grave national concern. In order to tackle the situation 0.5 to 2 million tonnes of vegetable oils and fats are imported every year and the short supply is only partially met. During the period of Fourth Plan the import bill of vegetable oils and fats totalled fourteen thousand and one hundred crores of rupees (T.O.I. Year Book, 1978) and the recent reports show that (T.O.I. Daily, 8th November, 1979) the import of edible oils is to continue and that it had already gone upto 1.4 million tonnes a year with an import bill of Rs. 800 crores (T.O.I. Daily, 3rd December, 1979). This is a heavy burden on the economy of a developing country like India.

It was realized that enhanced indigenous production of oil seeds (T.O.I. Daily, 12th October, 1979) only can save the country from the present situation and efforts have been made and are being made to increase the production of oil seeds in India. Statistical reports from 1949 (Anonymous, 1977) onwards show that there is no increase in the production rate, per head, of traditional oil seeds such as groundnut and sesame in India, primarily because of lower rate of productivity and the steady increase in consumer population. In order to overcome this drawback the search for new sources of vegetable oil continues and the efforts for improving the varieties and production technology of the new and traditional oil crops are being toned up. Sunflower (<u>Helianthus annuus</u> L.)- an already familiar plant grown in India since long for its ornamental value - is one among the new oil seed crops that has appeared on the scene and seems to stay. Niger (<u>Guizotia abyssinica</u> Cass.) is another promising oil yielding plant.

Sunflower (Helianthus annuus L.) is an annual herb of temperate origin, belonging to the family Asteraceae (Compositae). It is found in a number of forms branching or non-branching, single-headed or multi-headed with yellow or red flowers. The variety used in the present study is non-branching and single-headed. The recognition of the economic utility of this aesthetically beautiful plant has resulted in its intensive cultivation, breeding and selection programmes and now it is well established as an important crop plant in the U.S.S.R., Argentina, the U.S.A., Canada, Italy, France, Chile, Australia and England. Sunflower, because of its economic importance, has drawn many countries like Rhodesia, Israel and Bangladesh to its cultivation to such an extent that it has become a threat to other traditional crops.

Sunflower, though of temperate origin is reported to be able to flourish in a number of varied climatic conditions with the remarkable ability to resist draught (Anonymous, 1972 a; Jensma, 1973 and Hoeppe, 1976). Seeds of Sunflower yield a very high percentage of quality oil, which is golden yellowish, semi-drying and edible. The seeds of recent Russian hybrids yield 53 to 54% of oil and there are reports of yield upto 58-60% (Hoeppe, 1976).

The oil yield of Sunflower is twice that of groundnut and sesamum (Raju and Varma, 1978). The high percentage (62.5%) of linoleic acid makes Sunflower oil a palatable cooking oil which is reportedly useful for consumption even by patients suffering from ailments caused by excessive cholesterol deposits. The semi-drying property of Sunflower oil renders it useful for industrial purposes. The utility of Sunflower plant as an ideal fodder crop adds to its economic importance. The plant can be fed to cattle as green fodder or converted to silage and the protein rich oil cake is a good poultry and cattle feed (Khan et al., 1969; Spers, 1970; Hoeppe, 1976; Rai and Shukla, 1977 and Sheafter et al., 1977).

Such multiple uses of Sunflower and its adaptability to a wide range of environmental conditions have enabled it to emerge as a new promising crop plant. The U.S.S.R. has produced a large number of varieties of Sunflower which are known for their high yield. Cultivars viz. VNIIMK 8931 (EC 68413), Peredovik (EC 68414), Armavirskj 3497 (EC 68415) and Armavertz (EC 69874) (all Russian varieties) and "Sunrise Selection", an American variety were introduced in India through Indian Agricultural Research Institute (I.A.R.I.) (Kumar et al., 1979) and field trials are conducted in different parts of the country.

Niger (Guizotia abyssinica Cass.) known in India as Kalathil, Ramtil, Khurasni and Payellu, is another economically important plant belonging to the family Compositae (Wealth of India Vol. IV, Maheshwary and Singh, 1965 and Hill, 1952). It is a scabrid erect annual herb, moderately branching and growing to a height of 34 cm - 2.04 m. Flower heads of 12 mm - 25 mm size with yellow ray florets are produced at the tip of branches. A plant may produce 20-40 heads and each head may contain 30-45 seeds (Chavan, 1961) that are 3 or 4 angled 5 mm - 13 mm long with a thick, black and glossy seed coat.

Niger reported to be a native of tropical Africa, is popularly cultivated in Africa, India, Germany and West Indies mainly for its oil (Hill, 1952). In India, it is grown extensively in Madhya Pradesh, Maharashtra, Karnataka, Bihar, Andhra Pradesh, and Tamil Nadu, with an all India production to the tune of 87000 tonnes of seeds per year (The Hindu, 2nd May, 1972). Niger seeds contain about 30-40% of oil (Ramakrishna et al., 1973 and Wealth of India) which is pale yellow, with little odour and pleasant nutty taste and drying properties (Hill, 1952), used mainly for culinary purposes, massaging, lighting and in soaps, paints and varnishes. Niger oil cake is a known cattle feed (Pandey, 1968) and the plant as a whole is used as silage (Chavan, 1961).

The most attractive point in niger cultivation is that it is a crop which can be successfully raised on hills and plains, where other crops cannot easily be grown (Tosh and Patro, 1975). With very simple preparation of land and with very little attention by way of manuring and irrigation. Though it is cultivated as a pure crop, mixed crop or as a hedge crop, mainly in the Kharif season, it can be cultivated all round the year (Pandey, 1968). The seeds may be sown by broadcasting or drilling. Sowing on ridges or transplantation also can be done. It yields 600-900 kg of seeds/ha in pure culture and 100-150 kg seeds/ha in mixed crop (Pandey, 1968). As the economically important yield of Sunflower and niger is of direct interest to man, the shortage in the edible oil will lead him to the intensive cultivation of these promising crops in the agro-ecosystem (crop ecosystem). Crop ecosystem is the main source of food for human populations and partly for the domesticated animals. The food crisis due to increasing human population is responsible for the green revolution because of which the production potential of these man made ecosystems has assumed new dimensions. Extending cultivable land and promoting yield by proper utilization of the resources, and management of environment form the pre-requisites for success of the green revolution. Suitable plants must be introduced because the net primary production of an ecosystem is not only dependent on environmental factors but also on the genetical make up of plants (Lewis, 1970). Above a certain point increased "yield" must come from the sacrifice of other parts of the plant which form the protective maintenance equipment of the plant. This may have undesirable ecological impact on the ecosystem. But man cannot afford to ignore the highly productive modern varieties of plants and the means for obtaining a good yield.

Odum (1971) after considering in detail the various ecological implications of intensive agriculture strongly advocates for wholely new agricultural concepts based on ecological principles for a long term balanced productivity from man's ecosystems. For achieving the goal of a balanced production a thorough understanding of the structure and function of the primary production system is highly essential.

Production is an ecosystem process and the basic or primary productivity is the rate at which the radiant solar energy is stored by photosynthetic and chemosynthetic activity of the producer organisms (chiefly green plants) in the form of organic substances in different compartments, such as root, stem, leaf, fruit etc. All these parts may not be of direct use to man from the commercial stand point but they are of immense value as they contain energy and the nutrients. The primary productivity, being a dynamic function, that is controlled by the genetical set up and environment of the plant, varies widely with the species and climatological regimes prevailing in different areas.

Increase in the dry matter production (in growth) is consequent on the operation of a system composed of many interacting subsystems or growth processes, such as photosynthesis, respiration, transpiration, uptake of water and nutrients and the partitioning of the assimilates between plant parts. Techniques used to quantify the components of growth (i.e. productivity) are collectively known as growth analysis. Growth analysis as it has been worked out by the British ecologists (Blackman, 1919; Briggs, et al., 1920; Williams, 1946; and Blackman, 1968) or with slight modification (Nichiporovich, 1967; and Ne cas, 1965) has been established as a standard method for estimating net photosynthetic production of plants and stands of plants. The need to analyse the primary production of plants was stressed by Boysen-Jensen in 1949. The growth analysis is based on certain primary values such as dry weight of plants or their parts and the dimension of assimilatory apparatus (leaf area, chlorophyll content etc.). These primary values are assessed in growing plant material at certain time intervals and from them various indices and characteristics are calculated that describe the growth of the plants and of their various parts as well as the relationship between the assimilatory apparatus and dry matter production. Growth analysis can be regarded as a useful approach to analysing net photosynthetic production by plants. If the biomass is harvested at relatively short time intervals the rate of production can be estimated from the increase in biomass. In ecosystems the rate of production of organic mass by plants is defined as the primary production over a certain period. This value being so called, Leith (1962, and 1965) defined primary productivity (i.e. the rate of production) as all material formed in a plant community per unit ground area per unit time. Rate of production can be measured in many terms such as increase in dry weight, organic matter, carbon, CO_2 or solar energy fixed etc. Leith's (1965) definition nearly coincides with those of the rate of dry matter production and crop growth rate (CGR) (Watson, 1952) which also is used in growth analysis. The most appropriate measure of growth, which is dependent upon the amount of growing material, is the Relative Growth Rate (RGR) (Briggs et al., 1920) or the efficiency index (Blackman, 1919). RGR is a differential value being proportional to the slope of the growth curve at any one point. RGR can be applied without knowing the size of the assimilatory apparatus. The same applies to the ratio of dry weight (of different plant organs to total dry weight) describe the biomass distribution within plants. A special case of such a case is called the harvest index or coefficient of economic yield (Nichiporovich, 1967) i.e. the ratio of dry weight of economically important parts to total dry weight of the plant.

Calculations of other characteristics used in growth analysis require knowledge of the assimilatory apparatus which is usually measured in terms of leaf area or otherwise defined as assimilatory surface area per plant or sample of several plants or per unit area of the ground. The leaf area is of great importance in the stands of plants and its proportion to ground area is called the leaf area index (LAI)(Watson, 1952).

One of the most important growth characteristic describing the net production efficiency of the assimilatory apparatus is the unit leaf rate or net assimilation rate (NAR) (Briggs et al., 1920; Gregory, 1926; Williams, 1946; and Coombe, 1960). Another important characteristic describing the relative size of the assimilatory apparatus is the leaf area ratio (LAR) (Gregory, 1926) which is the ratio between leaf area and total dry weight.

Apart from the primary purpose of assessing the productivity, growth analysis can also be used to investigate ecological phenomena such as the success of the species in various habitats, or competition amongst species, or genetic differences in yielding capacity and effects of agricultural treatments on crop growth rate etc. In general, all applications of growth analysis may be regarded as investigations of one or both of the following :

(a) The dependence of the production capacity of the plant genotype on internal factors e.g. in comparative investigations of production and growth amongst varieties, species, populations or communities. This covers both genotypic and phenotypic differences.

(b) Production and growth as affected by environmental factors e.g. in ecological and agronomic investigations of the influence of climate, weather and edaphic factors on the rate of dry matter production and its components.

In the context of growth analysis the amount of chlorophyll present in plants represents, a measure of the size of the assimilatory apparatus which can be correlated with the rate of dry matter production and with other growth characteristics. Sprague and Curtis (1933) found that the amount of chlorophyll present in leaves or whole plants of maize was correlated with leaf area and growth rate. The existance of such relations was confirmed by Bray in 1960. Pilat (1967) found a linear relationship between the amount of biomass produced and the chlorophyll weight present per unit ground area. In white mustard Leith (1965) found the same kind of relationship between chlorophyll present in the plants and Crop Growth Rate as there was relation between LAI and CGR. Aruga and Monsi (1963) arrived at a similar conclusion. Okubo, et al. (1964) and 1968) used the term chlorophyll index which is defined analogously with LAI as gram of chlorophyll present in a stand per unit ground area.

In most productivity studies root production is assumed to be a certain proportion of above ground productivity based on the measures of root standing crop (Bray, 1963; Monk, 1966; Kelley, 1968, 1975; and Hunt, 1975, and 1976). Root/shoot ratios vary widely with the kind of plants and with the environmental conditions (Bray, 1963; and Odum, 1971).

Using these methods of growth analysis many workers have carried out several productivity studies in India (Misra, et al., 1967; Dwivedy, 1970; Mall and Singh, 1971; Ramakrishnan and Kumar, 1971; Kothari, 1972; Misra and Pandeya, 1972; Gopal and Maurya 1975 among others).

In the present study the primary productivity and the yield in the economic (commercial) sense of Sunflower and Niger under the agroclimatic conditions in Baroda are assessed.

A good amount of work mainly on the agronomic aspects of Sunflower has been done and reported. Much attention was paid to the study of the effect of fertilizers on the seed yield and seed oil content.

There are several reports that Sunflower respond well to fertilizer applications. Onishchenko (1968) found that an application of 120 kg of N and 120 kg of P_2O_5/ha increased the yield and protein content of seeds but decreased the oil content. Massey (1971) reported that nitrogen when applied at the rate of 56 kg/ha increased the seed yield, weight of the seeds per head, seed size and diameter of the head to 653 kg/ha, 17.7 g, 1.9 g/200 seeds, 2.2 cm and 11 cm respectively. D'yakov (1971) also reported that increased rates of application of nitrogen would increase the seed yield. He suggested that N if applied at right time and in right dose will not decrease the oil content of the seeds.

An application of N, P, and K fertilizers was found to be effective in improving the yield of Sunflower in sandy soils which is deficient in nutrients. Cernea and Tarau (1969) found that when CV VNIIMK 8931 was given 20 tonnes of farm yard manure and 180 kg of Superphosphate/ha or NPK (200 kg of ammonium sulphate + 300 kg of Superphosphate + 150 kg of potash/ha) the seed weight increased and the potash increased the oil production. This nutrient treatment also resulted in an increase in the number of leaves produced per plant. Plant growth also was found to increase upto 30 to 60% in pot trials as a result of added phosphorus and nitrogen fertilizer. And it was noticed that higher the fertilizer doses higher the density of roots. The effect of NPK on the seed yield and oil content of seeds was studied by many workers (Stevenson, 1970; Mian, _et al_., 1971; Tsurkan, 1972; Bamdad, 1972; Thaker, 1972; Gaur _et al_., 1975; Vicentinii and Anelli, 1973; Sivakumar _et al_., 1973; Khattak _et al_., 1973; Singh _et al_., 1973; Zubriski and Zimmermann, 1974; Ramaswamy et al., 1974 and Shanthanamalliah, et al., 1976; among others).

At Anand (Anonymous, 1972) maximum yield of Sunflower was obtained with an application of 60 kg of N and 90 kg of P_2O_5 followed by 90 kg of N and 60 kg of P_2O_5. Gour et al. (1973) in Rajasthan conducted an experiment on Sunflower with four levels of nitrogen and phosphorus each at 0, 25, 50 and 75 kg/ha. They reported that increasing levels of nitrogen increased the seed yield. Application of nitrogen at 0, 25, 50 and 75 kg/ha produced 1021, 1207, 1392 and 1457 kg of seeds/ha respectively.

Though in general the reports reveal that NPK fertilizers have positive effect on the yield of Sunflower an explanation to the difference in the quantity of NPK suggested for application may be found in the opinion of Robinson (1973) that the yield depended more upon the type of soil. He found that nitrogen failed to increase the seed yield on fertile silt loam soil, but on sandy soil added nitrogen increased the yield. D'Yakov (1974) suggested that only the maintainance of the optimal density of stands provided the full and the most efficient utilization of environmental resources.

The difference in the time of application of the fertilizers also show distinctively different effect on

Sunflower. An increase in nutrition before flowering influenced the production of the number of seeds per capitulum and the average weight of the seed. Late application of nitrogen (i.e. after flowering) increased the average weight of the seed and increased its protein content (Coic et al., 1972). Gour et al. (1975) reported that Sunflower gave a higher yield when nitrogen was applied in two split dressings (25% to the soil and 75% as foliar application).

The importance of water as a factor for the proper performance of any plant is an accepted fact. The yield of Sunflower also greatly depends on the moisture status of soil at the stage of budding, flowering and grain formation. The activation of growth processes conditioned by high content of mobile water results in a change in the ratio of reproductive to vegetative organs. Simanskii (1961) stated that the seed yield of Sunflower is strongly influenced by moisture stress at flowering. Watson et al. (1970) reported that Sunflower yields well in draught too. CV Peredovik gave a yield of 1660 lb/ha even though the rainfall between sowing and harvest was only 6". Karami (1977) tested the effects of 4 irrigation intervals on the yield of Sunflower and found a significant increase in yield under irrigated conditions and the highest yield was recorded when plants were irrigated at an interval of six days. Increase in the interval between irrigations reduced the yield of achene, height of the plant and weight of 1000 achenes, decreased with increase in interval of irrigation. The number of filled seeds and the oil content of seeds also decreased with long intervals between successive irrigations. It was found in Pantnagar that witholding of irrigation on 30th and 60th days after sowing may cause reduction in yield even in spring also, if the rain fails (Anon, 1977). A reduction in the leaf area of Sunflower under moisture stress conditions has been reported by Martin (1940). This reduction was found to be associated with the reduction in the size of the leaves.

All these reports show that although Sunflower can grow in draught, the yield and morphological aspects will be affected by moisture stress especially at certain stages of the growth of the plant.

Blackman and Wilson (1951 a) exposed Sunflower plants in different stages of its early vegetative development to a range of light intensities and found that net assimilation rates were not dependent on the age of the plant though there were significant differences in the Relative Growth Rates. Leaf Area Ratios were affected both by light intensity and stage of development. Blackman et al. (1955) in a pot culture found that leaf weight ratio is not controlled either by light or mean temperature and that the temperatures have positive effect on the Relative Growth Rates, and root weight ratio. They also found that the rate of leaf growth (on the basis of area or weight) together with the Net Assimilation Rate (area basis) and RGR of the whole plant and stems are directly and positively correlated with temperature and light. The leaf area ratios are suppressed by increasing light but augmented by raising temperature.

High temperatures during grain filling and ripening were found to cause low linoleic acid content and hence poor quality of oil (Kinman and Earle, 1964; Canvin, 1964; Hoeppe, 1976).

Wilson (1966) reported that the Net Assimilation Rates of Sunflower reached a 2.0 g dm^2 wk^{-1} in clear weather at mid-summer in an arid climate, when the plants were widely spaced and the soil nutrients and water were non-limiting. The high rates of assimilation is reported to be in response to the high level of radiation in the arid climate implying that (given non-limiting soil) plants can attain higher productivity in the arid climate. In young Sunflower plants grown widely, spaced on nutrient culture in an arid climate in which temperature varied from 8.5°C to 22.8°C Net Assimilation Rate rose linearly with radiation. Relative Growth Rate rose with radiation and temperature and Leaf

Area Ratio rose with increase in temperature or decrease in radiation. The variation was due to change in leaf area/ leaf weight rather than change in leaf weight/plant weight (Warren Wilson, 1966, 1967). Oikawa (1969) analysed the growth in height of Sunflowers which were in competition for light employing different densities such as 8.2, 25, 100 and 400 plants/m^2. He proposed a relative elongation rate which was adapted for elucidation of the pattern of growth in height of plants.

Eged s *et al.* (1971) observed that there is a seasonal change in growth rate of Sunflower. The seasonal change in the RGR was more influenced by photosynthetically active radiation (FAR) and by average temperature. Net Assimilation Rate was highest in July and it was positively correlated with FAR, Eze (1973) reported that the vegetative growth rate in sand culture was very high and the RGR was positively dependent on light and temperature, while the NAR was negatively dependent on light. All parameters except leaf area and leaf area to leaf weight ratio showed seasonal variation corresponding to dry and rainy season. Doyle (1975) studied the phenological development of a range of Sunflower cultures for a series of planting dates in New South Wales.

The formation of the number of leaves and total leaf area per plant though mainly depend upon the genotype it is affected by the various other factors also (Tsvetkova, 1975). Due to water stress the size of the leaves of Sunflower gets reduced resulting in a decrease in the total leaf area (Martin, 1940; Marc and Palmer, 1976). The number and area of the leaves of Sunflower plants were also found to be affected by sowing dates. The leaf area ranged from 14370 to 27500 m^2/ha depending upon the growing condition and genotype. The plants raised by sowing the seeds in April attained a leaf area of 25000 m^2/ha and gave the highest yields (Tsvetkova, 1975). Robinson (1970) could observe a difference in yield due to difference in the dates of sowing. Best result was obtained from a sowing in early May. Johnson and Jellum (1972) studied the effects of different planting dates on the yield, oil and plant characteristics of Sunflower in Georgia. They obtained highest yield of seed and oil content of seeds when planted from mid March through April. The planting in June gave low percentage of oil content in seeds. Fatty acid composition of seed oil varied considerably with different planting dates. When dates of planting were delayed from March till July the number of days taken from planting till flowering and that from planting till maturity decreased; head diameter and weight of the seed tended to decline. They concluded that dates of planting affected seed yields more than any other characteristics studied. They also found that height of the plants did not show any consistant trend with dates of planting in Georgia. Plantings of Sunflowers in May generally produced high seed yields in Minnesota (Robinson, 1971; Robinson et al., 1967) and in Canada (Putt, 1972). But cultivation in June resulted in low yields (Robinson et al., 1967). The percentage of oil content in seeds tended to decrease from May to late June plantings (Robinson, 1970) or when the crop was grown in temperatures either lower or higher than 21°C. Bhattacharya (1975) and Bhattacharya et al. (1975) conducted an experiment, in West Bengal, in which seeds of EC 68414 were sown spaced at 15 days intervals starting from November 28, 1974 to January 28, 1975. Higher seed and oil yields were obtained in early sowings which suggested that for successful cultivation of Sunflower, sowing must be done between last week of November and mid-December. The crop under delayed sowing was adversely affected by higher atmospheric temperature and low humidity during active vegetative growth, floral development and maturation stages. Proper time of sowing will vary from country to country which are climatically and edaphically different. The time of sowing is a factor which will affect the yield of seed and yield of oil from Sunflower (Mazjid and Atharuddin, 1976). In Bangladesh sowing period from September to November was found to be optimum for

HoI American variety while sowing period from February to July reduced the yield of this variety. When August to January periods favoured the highest amount of seed oil of the HoI variety, February to June sowing period was found to be the most favourable for the local variety (Mazjid and Atharuddin, 1976). They also found that the period of vegetative growth of Sunflower depended on the time of sowing of seeds. When sown in February the vegetative growth covered a period of 45 days, whereas in a sowing in December it extended to 74 days. In general, the most favourable time for sowing depends upon the rainfall and the variety selected. The reduction in the oil content is attributed to the high temperature especially to the higher night temperatures. Thus the cooler areas and seasons help to produce more seed oil (Hoeppe, 1976). Sunflower trials carried out in Bangalore showed that it was a crop which can be cultivated round the year giving the highest yield of 1.54 to 1.56 t/ha, when sown in June and September (Shanthanamalliah et al., 1976). At Pantnagar cultivation in rabi season gave the highest yield when planting was done in late December. Spring season crop performed better when sown from last week of January to first week of February. Delayed planting resulted in a reduction of yield mainly on account of poor growth and onset of monsoon (Anonymous, 1977).

The head or capitulum of Sunflower is an important part as the region where the seeds are formed. The size of the head should be considered as an index of yield from plots of Sunflower (Burns, 1970) on the ground that the size of the head was closely correlated with yield per head thus providing an estimate of yield. When raising cultivars smaller size of heads is considered as more desirable as it would decrease the damage of the yield by lodging of the plants. The size of capitulum and stem diameter have been found to be negatively correlated with the percentage of filled seeds (Khanna, 1971). Galgoezk (1968) found that the size of the heads could be increased by decreasing the density of the plant stand and also by application of an increased dose of NPK fertilizer. Similar reports were made by Bamdad (1972); Gour et al. (1975); Zubriski and Zimmermann (1974). Massey (1971) reported an increase in head diameter with an increase in plant spacing and that the yield decreased per area but the yield per plant increased. The correlation between the size of the head and density of plants was reported by Zubriski and Zimmermann (1974); Miller and Fick (1978), Karami (1977) found that head diameter was decreased with increase in irrigation intervals.

The time and mode of application of fertilizers were found to affect many characters such as the test weight of

1000 seeds, seed oil content etc. The application of phosphorus fertilizer right at the time of sowing than at a later stage of the plant growth such as stage of head formation was found to increase the 1000 seed weight to the maximum.

Varieties of Sunflower show difference not only in their yield characteristics but also in the vegetative characteristics, such as the thickness and length of the stem. Dwarf but high yielding varieties are preferred to agricultural purposes in order to avoid certain undesirable aspects such as lodging of the plants. Therefore, the height of the plants had been a matter of concern for Sunflower researchers. This character of the plant was found to be affected not only by the genetic constitution of the different varieties but also by other factors such as fertilizers, crop seasons, density of the stand etc. Among the NPK fertilizers, nitrogen was found to increase the stem height (Gour, et al., 1973); Bamdad, 1972; and Girase, et al., 1975). Massey (1971) found that the plant height and stem diameter were increased by 11 cm and 4 mm respectively, with an application of 56 kg of N/ha, over control. But any further increase in N did not make any significant difference. The stem diameter also was found to increase by only low levels of nitrogen (Sameni, et al., 1976). In a culture experiment application of N above 25 ppm did not result in any corresponding increase in stem diameter.

The height of the plant was found to be increasing with increase in density (Miller and Fick, 1978) probably as a result of competition for light. Karami (1977) found a decrease in the height of the plant in proportion to increase in irrigation intervals. There are contradictory reports regarding the growth in height of the plants in different seasons. When Premsekhar (1973) from Coimbatore, reported that the vegetative growth of the plants as evidenced by the height of the plants was more pronounced in winter when compared to that in rainy season. Bhattacharya et al. (1975) from West Bengal found that the variety EC 68414 attained a height of 125 cm in November and the height gradually decreased in latter sowings and in the sowings in January the plants attained a height of only 111 cm.

In Anand (Anonymous, 1972) the number of leaves was not affected by N and P fertilizers under dry land conditions. Cupina and Jocic (1972) reported that leaf area was increased more by N than P or K and most by NPK together. Density is another factor that affects the leaf area.

The leaf area of Sunflower is positively correlated with yield (Cupina and Jocic, 1973). This may be the reason for the observation of Johnson (1972); and Dhopte and Upadhyay (1975) that defoliation of any degree results in a reduction in the yield and seed oil content.

Ondok et al. (1972) determined the NAR and RGR of CV Polestar from weekly increments of the total biomass and leaf area. They found a more pronounced constancy of prediction in NAR rather than in RGR. NARs were found to be negatively dependent on relative humidity and LARs negatively dependent on light (Eze, 1973). The effects of light and temperature on the NAR, LAR and RGR were reported to be varying with species (Rajan et al., 1971). RGR and NAR were found to increase under optimum temperature but LAR was the largest at lowest light intensity. Hegarty (1973) reported that NAR of sunflower was positively dependent on radiation and temperature and RGR on radiation, temperature and initial LAR, Varghese et al. (1976) found that NAR of Sunflower was negatively associated with LAI and the LAI was markedly increasing with increase in N from 0 to 90 kg/ha and also with increase in P_2O_5 from 0 to 90 kg/ha but to a lesser extent.

Though Niger is known to be a less demanding plant, application of fertilizers have been tried to improve its yield. Bhattacharya (1973) studied the response of Niger to

N, P, and K with and without lime in lateritic acid soils. His results suggested that a pretreatment with lime as an essential step for successful cultivation of Niger in lateritic acid soils. The application of Nitrogen to a range of 22.5 to 45 kg in combination with 22.5 kg of Potassium (K_2O)/ha has produced pronounced effect on the vegetative growth, number of capitulum per plant and seed yield with a margin of 200% increase in yield over control. Singh and Verma (1975) found that the seed yield from Niger increased from 393 to 502 kg/ha when Nitrogen rates were increased from 0 to 40 kg/ha and 431 to 504 kg/ha when P_2O_5 was increased from 0-40 kg/ha and from 450-473 kg/ha with increase in K20 rates from 0 to 25 kg/ha. It was also reported that applied phosphorus increased the seed oil content but N and K had no effect on this. An application of FYM and Nitrogen was also found to increase the yield (Bhosale and Patil, 1977). The application of FYM (400 kg/ha) increased the seed yield to 204 kg/ha whereas the yield in control which did not receive any fertilizer was 180 kg/ha. The increase in N rates (0-12.5, 25, and 37.5 kg/ha) increased the yield from 136 kg to 174 kg, 203 kg and 228 kg/ha. In Maharashtra the seed yield was doubled as a result of the application of 5 tonnes of farm yard manure and 20-40 kg Nitrogen/ha to Niger in a density of 500,000 plants/ha, compared with the conventional practice of sowing by broad casting at a density of 166666 plants/ha without fertilizer. Generally, an application of green manure or 3 to 4 tonnes of FYM/ha in 3 to 5 times ploughed field and a top dressing of ammonium sulphate to supplement 60 kg N/ha is essential for a good yield of 600 to 900 kg/ha in pure culture and 100-150 kg/ha in mixed crop (Pandey, 1978).

Density of stand is having effect on the yield of Niger. Niger seed sown in rows 20, 30 or 40 cm apart with a distance of 10 cm between plants yielded 501, 481 and 440 kg of seeds/ha respectively and 437, 552 and 442 kg of seeds/ha with plants at a distance of 15 cm apart. Rao, et al. (1976) reported that Niger when grown at a density of 166, 666 to 666,666 plants/ha gave the highest yield of 1.05 t/ha with 166,666 density (i.e. 60 X 10 cm spacing) and the lowest yield of 0.56 t/ha with 533,333 plants/ha (60 X 5 cm spacing). Bhosale and Patil (1977) employed a 30 cm distance between rows and a seed rate of 4 kg/ha for sowing Niger. Singh and Verma (1975) reported that Niger gave a yield of 477,290 and 229 kg/ha when sown on 18th July, 17th August and 16th September, respectively and 340, 347 and 309 kg/ha with an inter-row spacing of 20, 30, and 40 cm respectively and 329 and 335 kg/ha respectively with 10 and 15 cm distance between plants. In Maharashtra the Niger seed yield was doubled when sown in August to early September in rows 20 or 30 cm apart with a density of 5000,000 plants/ha. compared with the practice of sowing in mid July at a density of 166,666 plants/ha (Patil and Tosh, 1978).

Kandaswamy (1973) in a correlation study in Niger found that the yield of the plant was positively correlated with height of the plant. The correlation between the yield, number of branches and number of capitulum was highly significant and the number of branches showed a significant positive trend in correlation to height of the plant. Oil content was negatively correlated with yield.

Recent reports show that in India steps are being taken to enhance the production of oil seeds like Sunflower, Niger etc. (T.O.I. 12th November, 1979) and the world is recognising Niger as an oil yielding plant with great future (Anonymous, 1977 a).

The present work on Sunflower and Niger has been taken up with a view to finding out the overall ecological performance of these two plants with respect to the primary productivity under different agroclimatic conditions in Baroda.

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