EFECT OF PLANT DENSITY AND NITROGEN ON FLOWER PRODUCTION AND QUALITY OF GOLDEN ROD (*Solidago canadensis* L.)

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EFFECT OF PLANT DENSITY AND NITROGEN ON FLOWER PRODUCTION AND QUALITY OF GOLDEN ROD (*Solidago canadensis* L.)

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CERTIFICATE

This is to certify that the thesis entitled "**EFFECT OF PLANT DENSITY AND NITROGEN ON FLOWER PRODUCTION AND QUALITY OF GOLDEN ROD (*Solidago canadensis* L.)**" Submitted By **Mr. Y.H. RYAGI**, for the degree of MASTER OF SCIENCE (AGRICULTURE) in HORTICULTURE of the University of Agricultural Sciences, Dharwad is a record of research work done by him during the period of his study in this university, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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Dedicated

To My Friend
Shri. S.Y. HUNGUND
and My Family Members

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Introduction

I. INTRODUCTION

Golden rod (*Solidago canadensis* L.) belongs to family compositae. The genus comprises about 130 species of perennial herbs and rarely a shrub. The genus is the characteristic of North Eastern America where about sixty species occur. There are several species on the Pacific coast, a few in Mexico and South America and two or three in Europe and North Asia. Though, it extensively finds it's presence in every garden and is also cultivated for cut flowers all over the world, statistics on it's area and production is not available.

Solidago canadensis is cultivated for it's attractive yellow coloured flower, flower panicle is arranged in rod shaped inflorescence, hence commonly called as golden rod. The common name refers to the appearance of flower. The herb is not mentioned much in ancient writings, but there is evidence that it was particularly promoted by Arabs, Italians and Germans as a wound healing herb.

Golden rods are also important flowers among the glories of the American autumn, where golden rods run in xanthic yellow and golden colours. Few species like *Solidago canadensis* , *Solidago virgaurea*, *Solidago memoralis* which are also grown in beds, borders or rock gardens and produce large panicles of yellow flowers for several months in a year, are popularly used as attractive cut flowers. Golden rod is generally used as a cut flower for indoor decoration in vases, it is used either singly or mixed with other flowers in flower bouquets and also it is used as a dry flower. Several interspecific hybrids have been evolved from *Solidago canadensis* and *Solidago virgaurea* which are more free flowering and have showy flowers than the parental species. Some of the popular cultivars are Ballardi, Golden Gates, Golden Wing and Peter Pan.

Solidago is a genus of hardy border perennials, two to four feet in height with a sparsely branched or unbranched stem, simple alternate leaves with small yellow and whitish heads in spikes. Flower is a spike and opens in basipetal manner from top towards bottom and has a good shelf life. They occur as common wild plants, and propagated by division of stools, suckers or seeds. The plants are easy to grow, they flower throughout the autumn and thrive in sun or shade in almost any soil.

However, a garden grown plant, with all the attention it deserves, not only grows larger but also blooms fuller and richer.

Essential oils, flavonoids, glycosides, tannins, saponins and various organic acids derived from *Solidago* are used as anti-inflammatory ointment for urinogenital and chronic skin problems, apart from being used as an adjuvant along with other remedies of benefit in asthama, arthritis and rheumatism.

A popular and an attractive cut flower like golden rod has a promising untapped export potential besides local demand for the Indian floriculture industry especially now, when it is estimated that the world consumption of floriculture products is worth forty billion dollars, of which the cut flowers alone contribute to nearly 60 per cent. While the global floriculture industry is growing at an annual rate of ten to fifteen per cent, Indian entry into the international trade could fetch an estimated foreign exchange of hundred crores, besides a promising annual growth potential of twenty five to thirty per cent. Inspite of all this, the golden rod being one of the most potential, beautiful and useful cut flower has been given less importance and no systematic research work has been done to find out suitable production technology for golden rod. Therefore, an investigation was carried out with the following objectives.

1) To find out the optimum plant density to improve the yield and quality.
2) To find out the optimum dose of nitrogen to get higher yield and quality flowers.
3) To know the effective combination of nitrogen dose and plant population on growth, yield and quality of golden rod.

Review of Literature

II. REVIEW OF LITERATURE

Light, temperature, humidity and nutrients are the most important limiting factors of plant growth and development. Amongst all those factors of production, balanced nutrition and optimum crop stand are most important in getting higher yield and quality produce. In nutrients, nitrogen is universally scarce in the soil and is the important limiting factor for production. So also plant population should not be too high or too low to maintain the plant growth and development. As commercial cultivation of golden rod is comparatively of recent one, the information on plant population and nutrition in golden rod is very meager. Therefore information in closely related crops like aster (*Callistephus chinensis* Nees.), chrysanthemum (*Chrysanthmemum morifolium* Ramat.), marigold (*Tagetes erecta* L.), zinnia (*Zinnia elegans* Jaca.), gerbera (*Gerbera jamesonii* Hook.),cosmos (*Cosmos sulpherians* willd.) and petunia (*Petunia hybrida* vilm.) are reviewed and presented here under.

2.1 EFFECT OF PLANT DENSITY ON VEGETATIVE AND REPRODUCTIVE GROWTH

Yokoi and Hosaks (1962) in their study on spacing methods and planting densities in china aster cv. otaki, observed that plant height, leaf size and number stem diameter, flower size and number were all less at closer spacings.

Yokoi (1966), reported that top growth and plant form were directly offered by the closeness of planting. Densely grown plants had a T-type branch formation with flowering occurring only on the upper tier. However, U-and V-type branching with the flowers borne on the middle and upper tiers of the plant were observed in widely grown plants in marigold.

Armbruster (1967) reported that the economic yields were obtained with 56 plants per sq. m in chrysanthemum cv. Indian Napolis. However, population density of $48/m^2$ was found good for quality flowers.

Joiner *et al.* (1967) noted that the total production increased but the quality of the flowers was decreased with closer spacing in chrysanthemum.

Janick and Durkin (1968) reported that flower size in green house grown chrysanthemum decreased with in creasing plant density. They also indicated the existance of inverse relationship between stem length and flower weight across the bench due to light factor which determined the density and seasonal effects on flower size.

Somoto *et al.* (1979) observed increased plant height, decreased number of leaves, stem diameter and the cut flower weight with increasing plant population in chrysanthemum.

Jaswinder Singh and Arora (1980) in their study on the effect of spacing and pinching on growth and flower production of marigold found that there was maximum yield of flowers per plant at widest spacing. Contrastingly, Ravindran *et al.* (1986) reported that when marigold (*Tagetes erecta* L.) was grown at 30x30 cm, 45x30 cm and 60x30 cm spacing, the highest flower yield was obtained with the plants spaced at 30x30 cm. Similarly, Kobza (1987) in his studies on china aster observed the increase in relative growth rate, plant productivity, net assimilation rate in the most closely spaced plants of 400x100 mm.

In china aster, Vijayakumar et al. (1989) spaced the plants at 30x10 cm, 30x20 cm, 20x30 cm and provided nitrogen at 180, 240, or 300 kg N/ha. The growth characters studied were leaf area index, total D.M. production, crop growth rate, RGR, NAR, and cut flower yield. They have reported that significantly higher cut flower yield (12.31 tonnes/ha) was obtained from plants spaced at 30x10 cm re ceiving N at 300 kg/ha. They also observed that, leaf area and leaf area index was increased with increase in plant density and dry matter accumulation was more in widely spaced plants. While, increased plant height and higher nitrogen uptake was observed at closer spacing, higher number of flowers per plant at wider spacing were recorded in their study.

2.2 IMPORTANCE OF PLANT NUTRITION IN FLOWERING PLANTS

Gruise and Joiner (1961) studied the flowering and chemical composition of zinnia and marigold, and opi ned that weekly application of a smallest dose (454.5 g per square foot) of 8:8:8: NPK fertilizer mixture for four weeks was sufficient for satisfactory growth and flowering. They also observed that, both low and high levels of nitrogen and potassium reduced the flower size and stem length and they suggested that application of optimum levels of nitrogen and potassium is found to be beneficial in aster.

Tsurishima and Date (1971) observed an improvement in vegetative growth and flowering with N and P application in marigold, pansies and zinnia.

Tayamna *et al.* (1974) reported that regular application of fertilizer had not only maintained sturdy growth of the plants but also improved the quality. Judicious and balanced application of nutrients resulted in overall improvement in quality of flowers and total flower yield in many crops (Elengovan, 1975, and Mantrova *et al.*, 1976).

Maheshwar (1977) did not observe any influence of nitrogen or phosphorous on time taken for 50 per cent flowering, but number of flowers, flower size and flower yield increased with increasing levels of N and P in china aster.

Ingawale (1979) reported that balanced application of nutrients brought about a significant increase in number of branches, plant spread, stem thickness, leaf area index and flower yield in marigold.

Nalawadi (1982) observed that application of 225 Kg N, 120 Kg P_2O_5 with 60 Kg K_2O increased the flower number, flower size, flower length, flower weight, flowering duration and flower yield significantly in all the eight varieties of marigold. However, more number of days were taken for commencement of flowering at higher levels of N and P.

Ramachandra (1982) reported that the delayed flowering, more number of flowers per plant and longer duration of flowering were observed at fertilizer levels of 120 Kg N and 60 Kg P_2O_5 per hectare in china aster.

Fischer and Benson (1983) stressing on the effects of N and P in asparagus stated that N and P increased the shoot dry weight, N increased the root dry weight, where as P decreased the root dry weight.

Jayanthi and Gowda (1988) reported that in chrysanthemum, 30 g N and 40g P_2O_5 per m^2 increased plant height, plant spread, number of shoots and total dry matter production.

Mantur (1988) recorded maximum flower yield per plant and per hectare with 180 Kg N,120 Kg P_2O_5,75 Kg K_2O per hectare in china aster.

Studies by Mokashi (1988) revealed that in gallardia cv. Kanabargi local, the increasing levels at N (150 to 250 kg/ha) and P (80 to 120 kg/ha) did not increase the plant height, number of branches, number of leaves, and plant spread.

In helichrysum the application of 150 kg N+ 100 kg P produced the tallest plants with more number of branches, leaves, leaf area and leaf area index (Sharanabasappa 1990).

2.3 NITROGEN AND ITS EFFECTS

Nitrogen is an important major essential element required for the normal growth and development of plant. It is the most mobile of all the mineral nutrients absorbed by the plant. Studies reveal that growth, flower production and flower quality in many ornamental flowers crops is greatly influenced by nitrogen.

2.3.1 Effect of nitrogen on vegetative and reproductive growth

Reports of several investigations on response of different flowering plants to different levels of nitrogen are reviewed here.

Rajeha (1966) reported that among all the essential nutrients required for flower production (many ornamentals), nitrogen was the most mobile of all mineral nutrients absorbed by plants.

Experiments conducted in India and elsewhere indicated that plant height, peduncle length, flower diameter and flower weight of china aster significantly increased with nitrogen application. Watson (1952) reported that leaf area index is more related to the crop yield as it forms the size of the photosynthetic system.

Lunt and Kofranek (1958) studied the importance of nitrogen at different stages of growth of chrysanthemum and stressed the importance of maintaining higher nitrogen levels in the growing media during the first seven weeks. They also noted that if moderate deficiency developed during that period, subsequent nitrogen fertilization would not be recaptured, the flower quality lost and also retardation of plants.

Penningsfeld (1973) studied the nutrient requirement of herbaceous plants and it revealed that phlox tolerated up to 300 Kg N per ha and chrysanthemum grew best with 200 Kg N per ha.

Shanmugam and Muthuswamy (1974) observed that a higher N content during early growth stage and moderate vegetative activity during the later stages is needed for early flowering and enhanced yield in chrysanthemum.

Arora and Saini (1976) obtained maximum number of flowers in china aster when N was applied at 200 Kg per hectare, but further increase in N levels at 300 and 400 kg per hectare resulted in reduced number of flowers.

Arthur and Hedley (1976) reported that reduced number of buds in snapdragons due to higher levels of nitrogen. On the other hand Hedley *et al.*(1971) obtained increased number of flowers per spike with higher nitrogen levels.

Maheshwar (1977) indicated that the plant analysis values for total N and total P at final stage of growth revealed a general increase in the uptake of each nutrient with the increasing levels of their application. He attributed this trend to their well developed plant structure and higher plant dry weight.

Nalawadi (1982) reported that with increment in N levels from 75 to 225 Kg per ha the dry matter production increased linearly as such, significantly highest total dry matter production was recorded at the highest level of N application in marigold. He also opined that the enhancement in different plant parts was due to increased plant height, branching, plant spread and leaf-area index and leaf area duration.

Natarajan and Rao (1983) reported that earliness in flowering was noticed with low N levels and high P levels in jasmine.

Chezhiyan *et al.*(1986) obtained increased flower number and maximum flower yield with the application of nitrogen upto 140 kg per hectare in chrysanthemum cv.CO-1

Ravindran *et al.*(1986) suggested that the highest flower yield (142.48 q/ha) was obtained at the highest nitrogen rate (90 kg/ha) in marigold.

Vijayakumar *et al.*(1989) obtained increased flower yield in china aster with the application of 300 kg nitrogen per hectare, but the increase in yield over other levels was not significant.

Anuradha *et al.*(1990) reported that significant increase in the number of flower per plant and weight of the single flower with increase in fertility levels from 0 to 90 kg of nitrogen and phosphorus per hectare in marigold.

Sharanabassappa (1990) reported significant increase in flower diameter, number of flowers per plant, flower yield per hectare with the application of 150 kg nitrogen per hectare in helichrysum.

Khimani (1991) obtained maximum flower yield in gaillardia by the application of 100 kg nitrogen per ha.

Joiner and Smith (1960) observed the direct relationship between growth and flowering time with increased levels of nitrogen in chrysanthemum.

Jungk (1962) in his experiment on chrysanthemum reported that increased levels of nitrogen increased the size and numbers of flowers.

Wordsworth and Butters (1973) reported that in chrysanthemum nitrogen application above 454 kg per ha enhanced the flower quantity in May-

August planted crop as compared to winter flowering crops and also higher nitrogen levels retarded the flowering date and shortened the vase life in winter.

Mantur (1988) noticed that the flower size was maximum with nitrogen at 180 Kg per ha, during *Kharif* and 240 Kg per ha during rabi season in china aster. Flower number was also found to be maximum with nitrogen at 180 Kg per ha.

2.3.2 Effect of excess nitrogen

Joiner and Smith (1960) reported that application of excess nitrogen to chrysanthemums caused drastic effect on growth and development.

Gruise and Joiner (1961) observed that both low and high levels of nitrogen and potassium reduced the flower size and stem length and they suggested that application of optimum levels of nitrogen and potassium is found to be beneficial in aster.

Waters (1964) in his nutritional studies indicated that excessive nitrogen in chrysanthemum manifested low marketable flower yield and dry matter production, he also observed that the keeping quality and colour intensity of the flower suffered due to increased supply of nitrogen.

Johnson (1976) reported that application of nitrogen above 330 Kg per ha in chrysanthemum reduced the yields.

Komosu (1978) observed in pot culture of chrysanthemum that high N rates retarded flowering duration and depressed the root growth. Excessive nitrogen increased susceptibility of the plant to grey mould (*Botrytis cinerea* pers.).

2.4 INTERACTION OF VARIOUS FACTORS

It is well known that the effects of one nutrient element could be modified by the presence of others.

Cook (1950) established the nitrogen and phosphorus nutrient balance on crop growth in calendula plants.

Tsurishima and Date (1971) observed an improvement in vegetative growth and flowering with N and P application in marigold, pansies and zinnia.

Steer *et al.* (1986) concluded in their studies on effect of nitrogen supply and population density in sunflower, that the increased N supply compensated the effects of dense population.

2.5 UPTAKE OF NUTRIENTS

Uptake of nutrients is governed by several factors viz., nutrient status of soil, climatic and plant factors.

Rennie and Soper (1958) suggested that placement of N over P_2O_5 fertilized bands increased the uptake of fertilizer P_2O_5.

Grunes (1959) studied the effect of N on the availability of soil and fertilizer P_2O_5 to plants and stated that addition of N stimulated the uptake of phosphorus. Similar results have been reported by earlier workers (Chapmen, 1936 and Lorenz and Johnson 1953).

Serra *et al.* (1975) studied the pattern of uptake of nutrients. They found a constant reduction in the stem nitrogen content as plants grew. In case of roots and leaves it fell initially and then increased.

Maheshwar (1977) indicated that the plant analysis values for total P at final stage of growth revealed a general increase in the uptake of each nutrient with the increasing levels of their application. He attributed this trend to their well developed plant structure and higher plant dry weight.

Nalawadi (1982) reported that application of 225 Kg N + 120 Kg P per hectare to marigold increased the total N and P uptake by 1.5 to 1.0 times more as compared to the application of 75 Kg N + 60 Kg P per hectare respectively at all the stages of growth.

Mokhashi (1988) reported that the uptake of nutrients by gaillardia did not commensurate with the increase n the level of application of nutrients. Sharanabasapa *et al.* (1990) reported that total nitrogen and phosphorus uptake increased with increase in nitrogen and phosphorus levels from 0 to 150 Kg per hectare.

2.6 CHEMICAL PRESERVATIVES AND FLOWER LONGEVITY

Use of preservatives to promote quality and prolong the vase life of cut flower is well known. These preservatives are mainly composed of sugars, germicides and other ingredients.

Working with different types of flowers and using different depths of water ranging from 1/2 to 1" Laurie (1936) concluded that the shallow water treatment increased keeping quality by 2-3 days mainly because less surface was exposed to bacterial decomposition in the water.

Staby and Erwin (1978) found that the composition of tap water varies greatly in various locations. This may influence the longevity of the flowers kept in tap water as well as the efficiency of chemical solutions used for holding, pulsing or bud opening.

Hitchcock and Zimmerman (1929) tried about 50 chemical in order to increase the longevity of cut flowers but none were found effective.

Kofranek *et al.* (1975) observed that china asters have lesser response to sucrose when used alone. Usually sucrose improves the water balance and osmotic potential of flowers.

Acock and Nichols (1979) recently confirmed that sugar improved the water balance and osmotic potential of carnation flowers.

Halevy and Mayak (1979) observed that aluminium sulphate at 50 to 100 ppm used in preservative formulations, reduces the transpiration, lowers the pH of petals and stabilizes the anthocyanin. Also, it reduced the bacterial growth by acidifying the holding water and improved the water uptake.

Wagner (1979) using direct analysis of isolated vacuoles from petals of hippeastrum and tulip demonstrated that glucose and fructose were located primarily in the vacuole.

Gowda (1986) studied the post harvest life of china aster and observed that vase life was longest with aluminium sulphate at 0.4 pr cent and 2 per cent sucrose.

2.6.1 Effect of Aluminium

Aluminium nitrate is one among the various bactericidal chemicals that have been evaluated commercially to improve cut flower vase life because of it's inhibitory property against microbial organisms (Rogers, 1973).

Aluminium sulphate proved effective in showing a greater percentage of full bloomed flowers and significantly promoted the vase life of cut tuberose (Mukhopadhyay, 1980).

Aluminium sulphate has been used in many preservative formulations for carnations (Schnabal, 1976), gladiolus (Mayak *et al.*, 1973 and Rameshwar, 1974) and other flowers (Ong team Taft, 1982 and Mohan Ram and Rao, 1977). Aluminium sulphate also acidifies the holding solution, thus reducing bacterial growth and improving water uptake (Halevy and Mayak, 1981). In chrysanthemum Al in the pulsing and bud opening solutions promoted foliage wilting (Kofranek and Halevy, 1972.)

2.6.2 Effect of sucrose

It is known that sucrose improves water balance in cut flowers (Aarts, 1957, and Halevy and Mayak, 1974).

Supplying cut flowers with exogenous sugar maintains the respirable substrates in the flower (Lukaszewska, 1986; Nichols, 1973; 1975), promotes respiration (Coorts, 1973; Wilkins 1973), encourages protein degradation (Coorts, 1973; Parups and Chan, 1973) and thus extends the longevity of cut flowers (Coorts, 1973 and Rogers, 1973).

The translocated sugars accumulated in the flowers increased their osmotic concentration (Acock and Nichols, 1979) and improved their ability to absorb water and maintained turgidity (Halevy and Mayak, 1974).

Sucrose enhanced the effect of cytokinin in delaying senscence of flowers and reduced the effect of ethylene, there by increasing the vase life of the flowers (Mayak and Dilley, 1976).

Sugars were found effective in inducing bud growth and development, delaying the abscission of buds and flowers and showing greater percentage of full bloomed flowers (Pathak *et al.*, 1979), thereby promoting vase life of cut tuberoses (Mukhopadhyay, 1980).

Sucrose in the vase solution was found to increase the vase life of china aster (Gowda, 1986), gladiolus (Anserwadekar and Patil, 1986; Bravdo *et al.*, 1974; Choi and Roh, 1980, and Lukaszewaska, 1981), daffodils (Piskornik and Piskornik, 1980), tuberose (BalKrishna, 1987), roses (Venkatarayappa *et al.*, 1981 and Nagarajaiah, 1985) and carnations (Caspvanaolocha and Esrivapianeras, 1978 and Lukaszewaska 1980).

Material & Methods

III. MATERIAL AND METHODS

Experiments were conducted in the Floriculture Unit, College of Agriculture, University of Agricultural Sciences, Dharwad, during kharif 1993-94, to study the effect of plant density and nitrogen levels on growth and flower yield of golden rod (*Solidago canadensis*L.) and also on the effect of chemical preservatives on vase life of golden rod flowers. The details of the materials used and the techniques adopted during the course of investigation are presented in this chapter.

3.1 EXPERIMENT-I:

EFFECT OF PLANT DENSITY AND NITROGEN LEVELS ON GROWTH AND FLOWER YIELD OF GOLDEN ROD

3.1.1 EXPERIMENTAL SITE

The experiment was conducted in the Floriculture Unit of New orchard, Division of Horticulture, UAS, Dharwad. Plate I gives a general view of the experimental site.

3.1.2 GEOGRAPHICAL LOCATION OF THE EXPERIMENTAL SITE

Dharwad is situated in the transitional tract of Karnataka at 15° 16' North latitude and 75° 07' East longitude at an altitude of 678 m above the mean sea level.

3.1.3 CLIMATIC CONDITIONS

The rainfall during the cropping period (July 1993-February 1994) of the experiment was 824.85 mm which was more than the previous 43 years. The

Plate 1. General view of the experimental site

maximum and minimum temperatures during the cropping period were 31.9 °C and 13.7 °C in the months of February and January, respectively.

The average annual rainfall is 840.7 mm and fairly distributed from June to December. February and March were the hot months with temperature ranging from 31.9 to 34.9 °C. December and January were the cool months temperature with ranging from 13.7 and 14.5 °C. The relative humidity fluctuated between 68 to 69 per cent. The meteorological data for the year 1993-94 and mean of last 43 years recorded at the Meteorological Observatory, Agriculture College Farm, Dharwad, are presented in Appendix-I.

3.4 SOIL OF THE EXPERIMENTAL SITE

The experiment was carried out in red sandy loam soil. Soil sample were collected from the experimental area upto a depth of 15 cm before conducting the experiment and were analysed for physical and chemical properties. The results of the soil analysis along with the methods followed are furnished in Appendix-II.

3.5 EXPERIMENTAL DETAILS

3.5.1 Design and Layout

The experiment was laid out in factorial randomised block design with three replications with a plot size of 3.15 x 2.4 m.

3.5.2 Treatments

There were 15 treatment combinations comprising of three levels of spacing and five levels of nitrogen.

Spacing levels and plant population in spacing

Spacing	Number of plants per plot	Number of plants/ha
S1 45 cm x 20 cm	84	1,11,111
S2 45 cm x 30 cm	56	74,074
S3 45 cm x 40 cm	42	55,556

Nitrogen levels

There were five levels of N with constant P_2O_5 and K_2O.

N_0	0:50:50 NPK kg/ha
N_1	25:50:50 NPK kg/ha
N_2	50:50:50 NPK kg/ha
N_3	75:50:50 NPK kg/ha
N_4	100:50:50 NPK kg/ha.

Treatment combinations

1) S_1N_0	(6) S_2N_0	(11) S_3N_0
2) S_1N_1	(7) S_2N_1	(12) S_3N_1
3) S_1N_2	(8) S_2N_2	(13) S_3N_2
4) S_1N_3	(9) S_2N_3	(14) S_3N_3
5) S_1N_4	(10) S_2N_4	(15) S_3N_4

3.5.3 PLANT MATERIAL

Suckers of golden rod from the Floriculture Unit, College of Agriculture, Dharwad were used for planting.

3.5.4 Fertilizer application

Phosphorous and potassium were supplied each at the constant rate of 50 kg/ha in the form of single super phosphate and muriate of potash, respectively. Nitrogen was supplied in the form of urea. The calculated dose of fertilizer was applied before transplanting, to each treatment.

3.5.5 Cultural operations

Hand weeding was carried out as and when required. The crop was irrigated depending upon the soil moisture status at an interval of 7-10 days. No pests and diseases were noticed.

3.5.6 Harvesting

The flower stalks were harvested at weekly intervals, when 20 per cent of the flowers in the stalk were opened. The harvested flower stalks were further used for recording different observations.

3.6 COLLECTION OF EXPERIMENTAL DATA

The observations on growth parameters were recorded at three stages of plant growth viz.,

I Stage - 30 days after planting.

II Stage - 60 days after planting.

III Stage - 90 days after planting.

For recording various bio-metric observations, five plants at random from the net plot were tagged in each treatment plots in all the replications, and were used for recording various observations.

3.6.1 Plant height

The plant height was measured from the base to the growing tip of the plant in cm for each of the tagged plants at different stages of growth and their average was worked out.

3.6.2 Number of suckers per plant

The number of suckers per hill were counted at 60 and 90 days after planting (DAP).

3.6.3 Number of leaves per plant

The number of leaves per plant in each treatment was recorded and the average was calculated at different stages of growth.

3.6.4 Dry matter production

Dry matter production was estimated at all the three stages of plant growth. Five plants were uprooted randomly from each treatment and from each replication. Then they were oven dried at 80°C to a constant weight and the total dry matter was recorded in grams.

This data formed the basis for computing crop growth rate, net assimilation and relative growth rate.

3.6.5 Leaf area

Ten leaves from each treatment were selected and a leaf bit from middle portion of the leaf was taken. The length and breadth were measured to know the area of the leaf bit. The dry matter content of these leaf bits and the remaining part of the leaves portion was taken separately. The proportion of leaf bit size to its dry matter content was calculated. This proportion obtained was used to calculate the leaf area for the remaining part of the leaf.

3.6.6 Days to first flower appearance

This observation was recorded by counting the days from the date of planting to the stage at which the first flower bloomed in each plot.

3.6.7 Days taken for 50 per cent flowering

The number of days taken for 50 per cent of the flowering each plot was recorded by counting the days from the date of transplanting.

3.6.8 Stalk length

Five stalks were selected randomly from five tagged plants and length was measured with the help of scale and average length in cm was calculated.

3.6.9 Flower yield

After recording the number of stalks from five the randomly selected plants, all the flower stalks were harvested and weighed and total yield of five plants was determined and average yield per plant was calculated.

The remaining flowers stalks in the net plot were harvested separately and weighed treatment wise, to which five flower stalks yield was added and based on total net plot yield, yield per hectare was calculated.

3.7 STATISTICAL ANALYSIS

Statistical analysis of the data was done by following the Fisher's analysis of variance technique as given by Panse and Sukhatme (1967). The level of significance used in "F' and "t" tests was P=0.05 and P = 0.01, respectively.

3.8 ECONOMICS

The cost of cultivation was worked out by taking market prices of different inputs. The cost of nitrogen, phosphorus and potassium were Rs. 6.10, 15.00 and 8.30 per kg respectively. Cut flower stalks were sold at the rate of 50 paise each.

3.2 EXPERIMENT-II

3.9 EFFECT OF CHEMICAL PRESERVATIVES ON VASE LIFE OF GOLDEN ROD

3.2.1 Preparation of flower for study:

One fourth opened flower stalk having uniform thickness of 35 cm length were selected randomly and were used for the study. Lower leaves were removed as a precaution to prevent them from touching the solution (Buys 1969). Two flower stalks were kept in each treatment and the flower stalks were placed in 250 ml conical flask containing 150 ml of chemical solution.

3.2.2 Treatments:

There were 3 chemicals each at a two concentration along with a control (tap water). Thus, in all there were 7 treatments replicated thrice.

1) Tap water (control)

2) Sucrose 0.1%

3) Sucrose 0.2%

4) Aluminium sulphate 0.2%

5) Aluminium sulphate 0.4%

6) $AgNO_3$ 0.02%

7) $AgNO_3$ 0.03%

The required amount of chemicals were dissolved in distilled water to get the solutions of concentrations mentioned in the treatments and these solutions were used for studying the vase life.

3.2.3 STATISTICAL DESIGN AND ANALYSIS

Experimental data was analysed following randomised block design with three replications by following Fisher's analysis of variance technique as given by Panse and Sukhatme (1967)

3.2.4 Observations

3.2.4.1 Water uptake

The difference between initial and final volume of solution remained in conical flask was recorded as the water uptake and expressed in ml.

3.2.4.2 Fresh weight

It is the difference between the initial and final weight of flower stalks. Based on this, the fresh weight was expressed as per cent change over initial weight.

3.2.4.3 Vase life

The point of termination of vase life varies from the first sign of wilting or fading to the death of flower stalks. Number of days at which flowers were found unfit for continuing in the vase was recorded as vase life.

Experimental Results

IV. EXPERIMENTAL RESULTS

The results of the experiment on plant density and the levels of nitrogen on growth and flower production of golden rod (*Solidago canadensis* Linn.) are presented in this chapter.

4.1 VEGETATIVE CHARACTERS

4.1.1 Plant height

The data on plant height as influenced by plant population and nitrogen at three stages of growth 30, 60 and 90 days after planting (DAP) are given in Table 1 and Fig 1.

As the growth advanced plant height increased from 9.23 cm at 30 days after planting to 68.34 cm at 90 days after planting.

Plant height was significantly influenced by spacing at all the stages of growth.

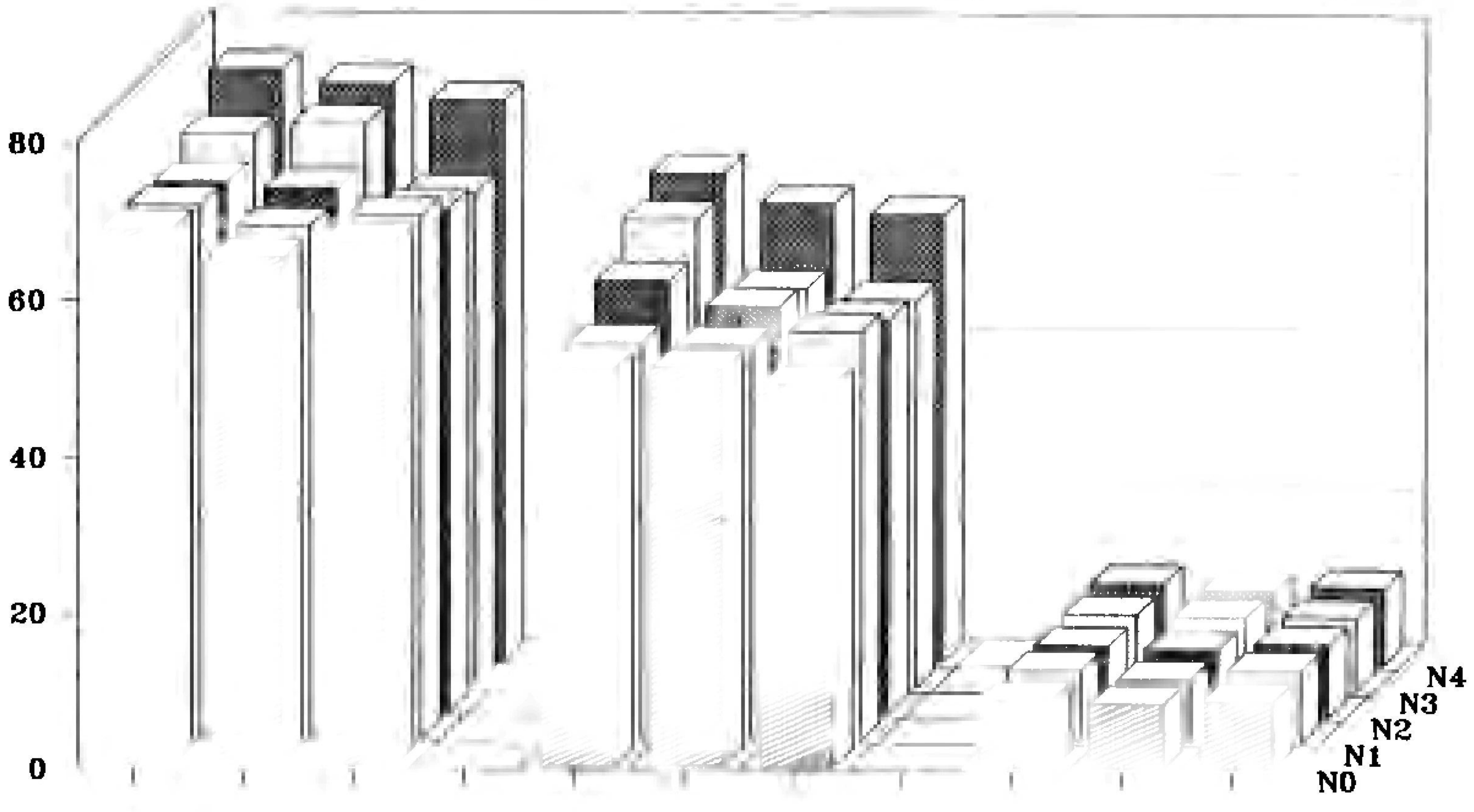
The maximum height of 9.49 , 55.95 and 70.15 cm was recorded respectively at 30, 60, and 90 days after planting (DAP) when the plants were spaced at 45cm x 20 cm (S_1). The difference was significant at 60 and 90 DAP over the remaining spacings adopted. However, at 30 DAP the height was non significant between the spacings 45 x 20 cm (S_1) and 45x 40 cm (S_3).

During various stages of growth, nitrogen showed significant effect on plant height. The tallest plants (10.04, 59.38 and 73.55 cm) were observed at 100 kg nitrogen per ha (N_4) at 30, 60 and 90 DAP, respectively. The fertilizer

Table 1. Influence of plant density and nitrogen on plant height (cm) at different stages of growth in golden rod

Treatment	30 DAP						60 DAP						90 DAP					
	N_0	N_1	N_2	N_3	N_4	Mean	N_0	N_1	N_2	N_3	N_4	Mean	N_0	N_1	N_2	N_3	N_4	Mean
S_1	8.73	9.13	9.04	9.73	10.46	9.49	51.03	51.04	55.44	59.93	62.33	55.95	68.73	68.30	67.83	70.50	75.37	70.15
S_2	8.26	8.00	8.67	9.43	9.53	8.70	51.17	50.81	52.29	51.17	58.60	52.81	65.00	65.07	67.10	71.97	73.73	68.57
S_3	8.67	9.33	9.40	9.60	10.13	9.27	49.16	52.56	50.70	49.72	57.20	51.87	65.30	67.00	64.57	63.14	71.54	66.31
Mean	8.56	8.82	9.16	9.59	10.04	9.23	50.45	51.47	52.81	53.61	59.38	53.54	66.35	66.79	66.50	68.54	73.55	68.34
For comparing:		S.Em±		CD at 5%					S.Em±		CD at 5%				S.Em±		CD at 5%	
S		0.133		0.384					0.733		2.124				0.417		1.209	
N		0.171		0.496					0.946		2.742				0.538		1.560	
SxN		0.296		NS					1.639		NS				0.932		2.702	

N = Nitrogen levels S = Spacing


80
60
40
20
0
N4
N3
N2
N1
N0

levels N_3 and N_4 (75 and 100 kg/ha) remained statistically on par with each other at 30 DAP. However, at 60 and 90 DAP, the fertilizer level 100 kg per ha (N_4) produced significantly higher (73.55 cm) plant height as compared to all other levels of nitrogen tried.

The interaction (SxN) was non significant for plant height at 30 and 60 DAP. However, in the final stage, the interaction was found significant the treatment combination S_1N_4 with the tolllest plant (75.35 cm) was significantly different with all other treatment combinations except S_2N_4. The minimum height (63.14 cm) was recorded in S_3N_3.

4.1.2 Number of leaves per plant

The data on number of leaves per plant was recorded at 30, 60 and 90 DAP and are presented in Table-2 and Fig.2.

The main treatments (spacing) had significant influence on number of leaves per plant. Significantly higher number of leaves were recorded in S_2(17.85) and S_1(37.09) at 30 and 60 DAP respectively. Although, S_3(50.44) had maximum number of leaves per plant at 90 DAP, it was statistically on par with S_1 (50.30).

The individual effect of nitrogen was found significant at all the three stages of plant growth observed. There was a gradual increase in the number of leaves with the increasing levels of nitrogen at 30, 60 and 90 DAP. While at the final growth stage, the highest level of nitrogen (N_4) recorded significantly higher (53.52) number of leaves than all other lower level, the number of leaves were least (47.72) in the control (N_0). The other levels of nitrogen (N_1, N_2 and N_3) did not differ significantly among themselves with respect to number of leaves.

Table 2. Effect of plant density and nitrogen on number of leaves at different stages of growth in golden rod

Treatment	30 DAP						60 DAP						90 DAP					
	N_0	N_1	N_2	N_3	N_4	Mean	N_0	N_1	N_2	N_3	N_4	Mean	N_0	N_1	N_2	N_3	N_4	Mean
S_1	12.13	15.20	15.87	16.27	19.70	15.83	32.13	35.60	36.90	39.47	41.35	37.09	47.61	49.29	48.91	51.33	54.40	50.30
S_2	17.07	17.07	17.40	18.13	19.60	17.85	35.63	36.67	34.56	32.11	37.64	35.32	48.31	43.64	48.75	46.81	52.67	46.03
S_3	15.20	16.47	16.73	17.00	19.73	17.03	32.67	30.04	34.22	35.38	38.11	34.08	47.24	49.20	51.14	51.13	53.50	50.44
Mean	14.80	16.24	16.67	17.13	19.68	16.90	33.48	34.10	35.23	35.65	39.03	35.50	47.72	49.60	49.60	49.76	53.52	49.59

For comparing:	S.Em± (30 DAP)	CD at 5% (30 DAP)	S.Em± (60 DAP)	CD at 5% (60 DAP)	S.Em± (90 DAP)	CD at 5% (90 DAP)
S	0.198	0.573	0.403	1.169	0.304	0.880
N	0.255	0.740	0.521	1.509	0.392	1.136
SxN	0.442	1.281	0.902	2.613	0.679	1.968

N = Nitrogen level S = Spacing

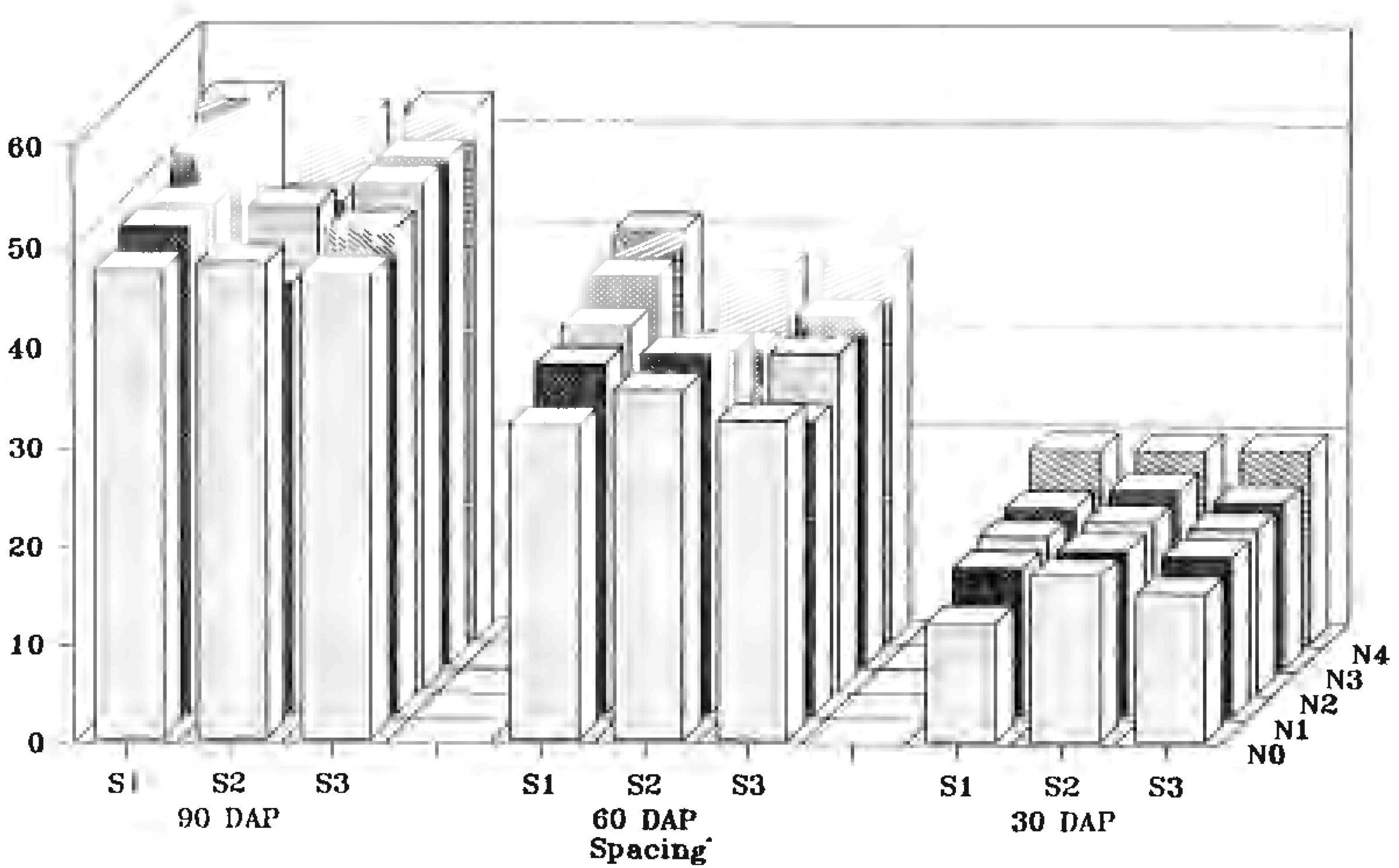


Fig. 2. Effect of plant density and nitrogen on number of leaves at different stages of growth in golden rod

The interaction effect was significant at all the stages of growth. The highest number of leaves per plant at 30, 60 and 90 DAP respectively were recorded in the combinations S_3N_4 (19.73) and S_1N_4 (41.35 and 54.40). While, the combination of N_4 with different spacings at 30 DAP were non significant, at 90 DAP the combinations S_1N_4 and S_3N_4 were not differing significantly. However, at 60 DAP, the combination S_1N_4 had significantly higher number of leaves per plant as compared to rest of the combinations. The combinations with lowest number of leaves at 30 60 and 90 DAP were S_1N_0 (12.13), S_1N_1 (30.04), and S_2N_1(43.64) respectively.

4.1.3 Leaf area per plant

The data pertaining to leaf area due to the effect of plant population and nitrogen are given in the Table 3.

The spacing had significant effect on leaf area of Goldenrod. While, the plants with least spacing (S_1) had maximum leaf area (198.78 cm^2) and the plants with highest spacing (S_3) had least (180.22 cm^2) leaf area.

The of varying levels of nitrogen had also significant effect on leaf area per plant. The highest dose of nitrogen (N_4) produced the plants with maximum (205.21 cm^2) leaf area, while the plants which did not receive any nitrogen (N_0) had significantly least (190.04 cm^2)·leaf area.

The interaction effects of spacing and nitrogen were also differing significantly. The maximum (207.72 sq. cm) leaf area per plant was recorded in the treatment combinations S_1N_4 which was significantly differeing with all other

Table 3. Effect of plant density and nitrogen on leaf area (cm^2/plant) at 90 DAP in golden rod

Treatmen	N_0	N_1	N_2	N_3	N_4	Mean
S_1	188.95	196.84	198.60	201.82	207.72	198.78
S_2	174.70	187.55	191.92	196.86	204.60	191.12
S_3	155.47	168.62	181.48	192.24	203.32	180.22
Mean	173.04	184.34	190.67	196.97	205.21	190.04

For comparing:	S.Em±	CD at 5%
S	0.531	1.539
N	0.686	1.987
SxN	1.188	3.442

combinations except S_2N_4 (204.60 sq. cm). The minimum (155.47 sq.cm) leaf area per plant was recorded in the interaction of S_3N_0 which was significantly lower compared to all other treatment combinations.

4.1.4 Plant canopy

The data on the plant canopy (sq.cm) collected at 90 DAP are presented in Table 4.

The plant canopy of golden rod was significantly influenced by plant density (spacing). The maximum plant canopy of 21.63 sq. cm was recorded in S_3 and it was significant over the remaining two spacings.

The individual effect of nitrogen had significant effect on plant canopy. The maximum plant canopy was observed in N_4 (23.43 cm^2) and the least in N_0 (17.91 cm^2). However, the canopy of plants in N_1 and N_2 did not differ significantly. The interaction effects were not significant though the the treatment combination S_3N_4 (23.80 cm^2) had recorded highest plant canopy and the least was with S_1N_0 (17.17 cm^2).

4.1.5 Fresh weight

The data on fresh weight as influenced by plant population and nitrogen are given in Table 5 and Fig.3.

As the growth advanced, fresh weight increased from (22.54 gm) at 30 DAP. to 76.64 gm at 90 DAP.

The plant fresh weight was significantly influenced by different spacings at all the stages of growth. Significantly higher fresh weight was recorded

Table 4. Influence of plant density and nitrogen on plant canopy (cm) at 90 DAP in golden rod

Treatmen	N_0	N_1	N_2	N_3	N_4	Mean
S_1	17.17	18.17	19.00	21.83	23.00	19.83
S_2	17.90	20.13	19.47	21.20	23.50	20.44
S_3	18.67	21.27	21.47	22.97	23.80	21.63
Mean	17.91	19.85	19.98	22.00	23.43	20.64

For comparing:	S.Em±	CD at 5%
S	0.201	0.584
N	0.260	0.754
SxN	0.451	NS

Table 5. Influence of plant density and nitrogen on fresh weight (g/plant) at different stages of growth in golden rod

Treatment	30 DAP						60 DAP						90 DAP					
	N_0	N_1	N_2	N_3	N_4	Mean	N_0	N_1	N_2	N_3	N_4	Mean	N_0	N_1	N_2	N_3	N_4	Mean
S_1	20.00	20.54	21.98	21.58	27.67	22.21	54.47	61.57	65.10	69.70	82.40	66.65	61.00	70.67	72.00	72.33	90.00	73.20
S_2	21.40	21.97	22.53	24.31	26.14	23.29	68.44	63.64	66.34	65.54	70.31	66.85	76.67	80.33	80.00	86.67	87.00	80.93
S_3	19.93	22.32	22.76	22.87	22.71	22.12	63.55	63.58	62.31	64.11	67.64	64.24	71.33	73.33	75.33	77.00	82.00	75.80
Mean	20.47	21.61	22.19	22.93	25.50	22.54	62.15	62.93	64.58	66.45	73.45	65.51	69.67	74.77	75.78	76.67	86.33	76.64
For comparing:		S.Em±		CD at 5%					S.Em±		CD at 5%				S.Em±		CD at 5%	
S		0.275		0.797					0.377		1.092				0.514		1.488	
N		0.355		1.030					0.487		1.410				0.663		1.921	
SxN		0.615		1.783					0.843		2.442				1.148		3.328	

N = Nitrogen level S = Spacing

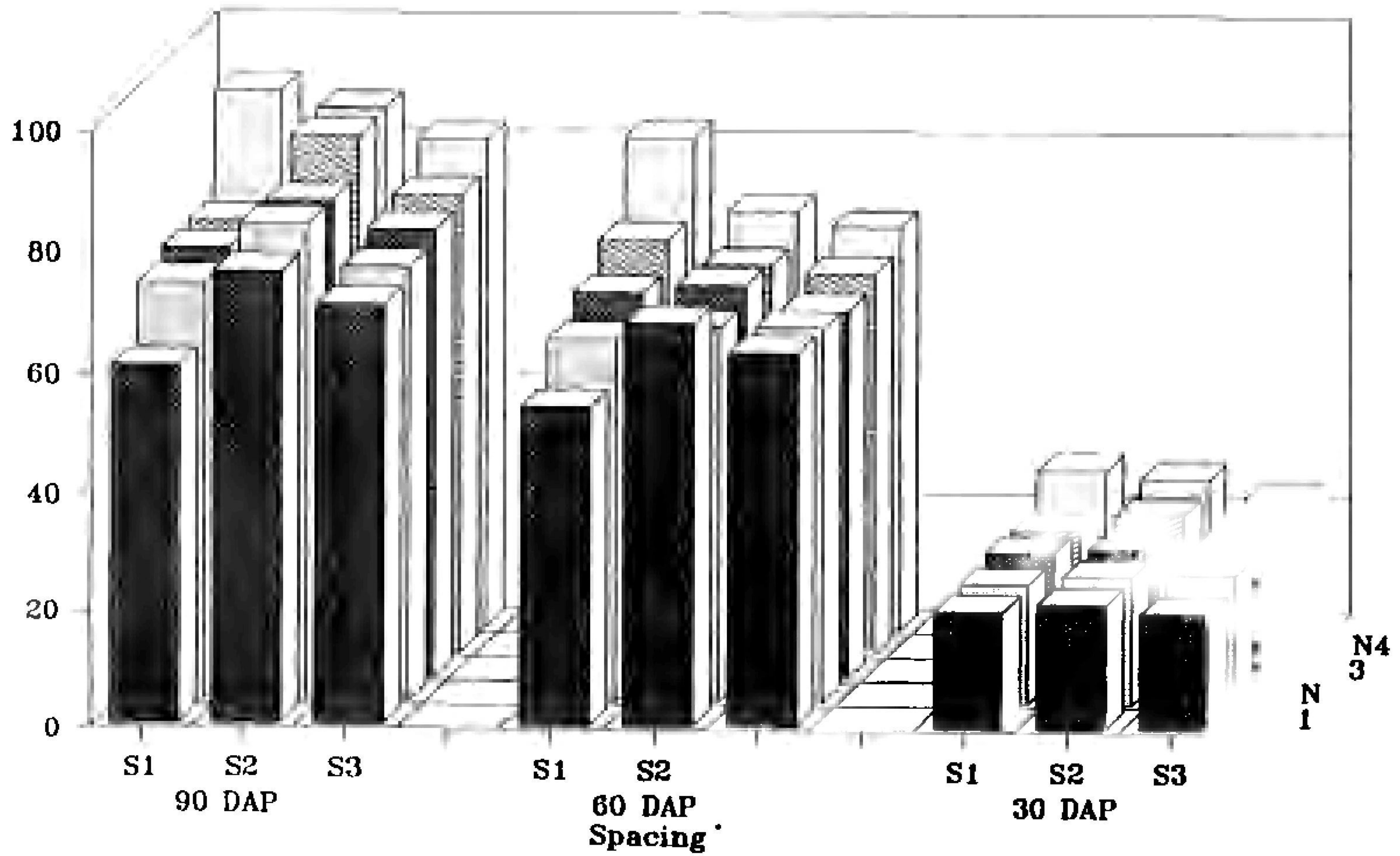


Fig. 3. Influence of plant density and nitrogen on fresh weight (g/plant) at different stages of growth in golden rod

in S_1 (23.29 gm) at 30 DAP. Though fresh weight was maximum in S_2 (66.85 gm) at 60 DAP, the spacingS_1 and S_2 had no significant difference. At 90 DAP, S_2 (80.93 gm) recorded maximum fresh weight which was significantly higher over other two spacings tried.

The influence of varying levels of nitrogen had significant effect on fresh weight. The increase in the levels of nitrogen have gradually increased the fresh weight throughout the growth period. The nitrogen at 100 kg per hectare (N_4) recorded significantly higher fresh weight (22.50, 73.45 and 86.33 g respectively) at 30, 60 and 90 DAP.

The effect of interaction was significant at all the stages of plant growth. The maximum fresh weight (27.67 and 90.00) was recorded in the combination S_1N_4 both at 30 and 90 DAP and was on par with S_2N_4. At 60 DAP, the maximum fresh weight of 82.40 g was recorded in S_1N_4, which was significantly superior over all other combinations. The lowest fresh weight was observed in the combinations S_3N_0 (19.93 g) at 30 days and S_1N_0 with 54.47 and 61.00 g at 60 and 90 DAP respectively.

4.1.6 Dry weight

The data on dry weight due to the effect of plant population and nitrogen are presented in Table 6 and Fig.4.

Dry weight increased from 16.10 to 26.67 g per plant with the advancement in growth from 30 to 90 DAP.

Table 6. Influence of plant density and nitrogen on dry weight (g/plant) at different stages of growth in golden rod

Treatment	30 DAP						60 DAP						90 DAP					
	N_0	N_1	N_2	N_3	N_4	Mean	N_0	N_1	N_2	N_3	N_4	Mean	N_0	N_1	N_2	N_3	N_4	Mean
S_1	15.73	16.46	16.39	15.49	18.94	16.60	18.97	21.02	21.13	19.42	24.57	21.04	26.93	27.60	27.60	29.17	32.50	28.91
S_2	15.77	15.37	15.36	15.66	17.84	16.00	18.03	18.30	21.24	22.87	22.40	20.77	23.50	25.00	25.00	27.83	31.50	26.71
S_3	15.67	15.18	15.49	15.89	16.23	15.69	18.09	18.09	20.81	21.89	19.51	19.94	21.17	21.67	23.30	25.17	30.67	24.39
Mean	15.72	15.67	15.75	15.68	17.67	16.10	19.13	19.13	21.06	21.39	22.19	20.58	23.87	24.76	26.00	27.12	31.56	26.67
For comparing:		S.Em±		CD at 5%					S.Em±		CD at 5%				S.Em±		CD at 5%	
S		0.149		0.433					0.244		0.708				0.204		0.592	
N		0.193		0.558					0.315		0.914				0.364		0.765	
SxN		0.334		0.967					0.546		1.583				0.457		1.325	

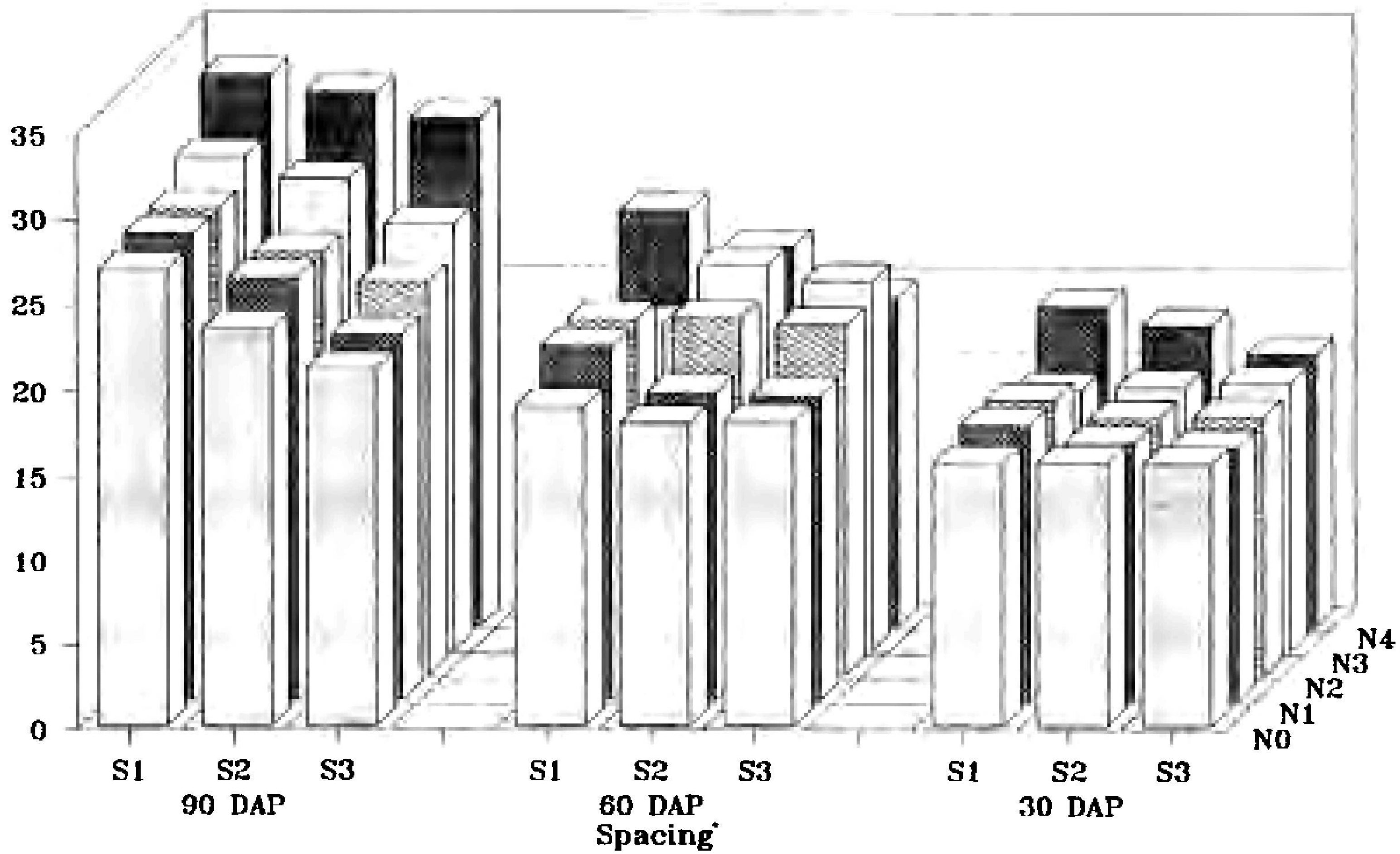


Fig. 4. Influence of plant density and nitrogen on dry weight (g/plant) at different stages of growth in golden rod

The spacing had significantly influenced on dry weight of the plant. The closely spaced plants (S_1) recorded significantly higher dry weight of 16.60, 21.04 and 28.91 g respectively at 30, 60 and 90 DAP.

Nitrogen also showed significant effect on dry weight on all the stages of growth observed. The maximum plant dry weight of 17.67, 22.19, and 31.56 g, were recorded by the plants supplied with highest dose of nitrogen (N_4) respectively at 30, 60 and 90 DAP, except N_3 level at 60 DAP.

The interaction effects of spacing and nitrogen were significant at different stages of growth. The maximum dry weight per plant was seen in S_1N_4 (18.94g and 24.67g) at 30 and 60 DAP respectively and was significant over all other combinations. At 90 DAP, the highest dry weight was although noticed in S_1N_4, this treatment did not differ significantly with S_2N_4. The combinations S_3N_1 (15.18 g and 18.09g at 30 and 60 DAP respectively) and S_3N_0 (21.17g at 90 DAP) recorded dry weight per plant.

4.2 YIELD AND YIELD ATTRIBUTES

4.2.1 Days for first flower opening

The data on days required for first flower opening is presented in Table 7 and Plate 2.

The influence of spacing on days required for first flower opening was found to be significant. The widest spaced plants (S_3) took minimum number of days (61.33) for first flowering and this was significantly differing with the remaining two spacings.

Table 7. Effect of plant density and nitrogen on days to first flowering in golden rod

Treatmen	N_0	N_1	N_2	N_3	N_4	Mean
S_1	58.167	59.500	61.833	63.167	67.167	61.967
S_2	59.833	61.667	62.667	65.000	67.833	63.400
S_3	59.167	60.000	61.000	62.167	64.333	61.333
Mean	59.056	60.389	61.833	63.444	66.444	62.233

For comparing:	S.Em±	CD at 5%
S	0.182	0.527
N	0.225	0.680
SxN	0.406	1.178

Plate 2. Photograph showing the first flower opening

The nitrogen levels also differed significantly with regard to the number of days taken for first flowering. In general, the days taken for first flowering increased with the increase in nitrogen level. Hence, the highest level of nitrogen (N_4) delayed the flower initiation most (66.44 days) as compared to N_0 (59.06 days).

The interaction effect were also found statistically significant with regard to the number of days required for first flower opening. While, the treatment combination S_2N_4 took maximum number of days (67.83) for producing first flower. The treatment combination S_1N_0 took least number of days (58.17 days) for first flowering.

4.2.2 Days required for fifty per cent flower opening

The data on days required for fifty per cent flower opening are presented in Table 8 and Plate 3.

It can be seen from the table that the plant density had significant effect on the days required for fifty per cent flower opening. The crop planted at 45x20 cm (S_2) took more time for fifty per cent flowering (73.60 days), followed by closely spaced (72.33 days) and the least by widest spaced plants (68.93 days).

Significant difference was also noticed among nitrogen levels on days required for fifty per cent flowering. The plants without nitrogen (N_0) took significantly more number of days (76.44) for fifty per cent flowering. The least time (68.89) taken for fifty per cent flowering was recorded in plants supplied with

Table 8. Effect of plant density and nitrogen on number of days for 50 per cent flowering in golden rod

Treatmen	N_0	N_1	N_2	N_3	N_4	Mean
S_1	79.333	76.333	73.333	68.000	64.667	72.333
S_2	76.333	78.333	76.667	71.333	68.333	73.600
S_3	73.667	70.667	68.333	67.333	64.667	68.933
Mean	76.444	75.111	71.778	68.889	65.889	71.622

For comparing:	S.Em±	CD at 5%
S	0.174	0.505
N	0.225	0.652
SxN	0.390	1.129

Plate 3. Photograph showing the 50 per cent of flowering

highest dose of nitrogen (N_4). There was progressive decrease in the number of days taken for fifty per cent flowering as the N level increased.

Interaction effect of spacing and nitrogen levels on days required for fifty per cent flowering was found to be significant. The treatment combination S_1N_0 took significantly more number of days (79.33) as compared to rest of the treatment combinations except S_2N_1. The treatment combinations S_1N_4 and S_3N_4 took minimum time (64.66 days each) for fifty per cent flowering.

4.2.3 Number of days for complete flowering

The results on the effect of plant population and nitrogen on the number of days taken for complete flowering are presented in Table 9 and Plate 4.

It can be observed from the table that the spacing levels had significant influence on the number of days required for complete flowering. The widest spaced plants (S_3) although took maximum (94.73 days) number of days for complete flowering, were found to be statistically on par with S_2. The closely spaced plants took least (86.4 days) number of days to complete their flowering.

The nitrogen levels did not influence significantly the number of days taken for complete flowering. However, the highest nitrogen level (N_4) took maximum number of days (93.33) and the minimum (89.67) days for full bloom were taken by the plants grown without nitrogen application.

So also, the interaction between spacing and nitrogen levels did not significantly influence the number of days taken for complete flowering. However the plants spaced at 45x30 cm with 50 kg nitrogen (S_3N_2) took more number of

Table 9. Effect of plant density and nitrogen on days to cessation of flowering in golden rod

Treatmen	N_0	N_1	N_2	N_3	N_4	Mean
S_1	82.667	87.667	84.333	87.000	90.333	86.400
S_2	92.330	93.000	93.667	91.000	95.000	93.000
S_3	94.000	93.667	96.333	95.000	94.667	94.733
Mean	89.667	91.440	91.440	91.000	93.333	91.378

For comparing:	S.Em±	CD at 5%
S	0.887	2.569
N	1.145	NS
SxN	1.982	NS

Plate 4. Photograph showing the complete flowering

days (96.33) followed by S_2N_4 and S_3N_3 each taking 95.00 days for complete flowering. The combination S_1N_0 took least number of days (82.67) for complete flowering.

4.2.4 Length of flower stalk (cm)

The results of the length of flower stalk are presented in Table 10 and Fig. 5.

The different plant densities showed significant effect on the length of flower stalk at 60 and 90 DAP. The lengthiest (27.44 cm) flower stalks were obtained in closely spaced (S_1) plants at 60 DAP, but by S_2 (29.99 cm) at 90 DAP. However, spacings S_1 and S_2 produced no significant difference with respect to the length of flower stalk at 60 DAP.

Nitrogen levels had exhibited significant differences both at 60 and 90 DAP. Significantly higher length of flower stalk was produced in N_4 (30.54 and 33.60 cm), while the flower stalks were shortest in N_0 (23.71 and 23.60 cm) at both the stages of growth. There was no significant difference between N_0 and N_1, and N_1 and N_2 at 60th day. So also, flower stalk length did not differ significantly between N_0 and N_1, and N_2 and N_3 at 90 DAP.

The interaction effect was found to be significant at 60 and 90 DAP. The flower stalk were lenghiest in the combination S_1N_4 (32.70 and 38.40 cm) at both 60 and 90th day of observations. These were statistically significant over all other combinations of spacing and nitrogen levels except in S_2N_4 at 60 DAP.

Table 10. Influence of plant density and nitrogen on length of flower stalk (cm) at 60 and 90 DAP in golden rod

Treatment	60 DAP						90 DAP					
	N_0	N_1	N_2	N_3	N_4	Mean	N_0	N_1	N_2	N_3	N_4	Mean
S_1	22.74	24.51	27.34	29.93	32.70	27.44	21.14	23.50	28.94	28.47	38.40	28.09
S_2	23.25	24.55	26.43	28.33	30.81	26.68	27.77	28.17	33.00	28.20	32.83	29.99
S_3	25.13	23.54	22.22	22.70	28.12	24.34	21.90	22.50	23.57	27.03	29.59	24.91
Mean	23.71	24.20	25.33	26.99	30.54	26.15	23.60	24.72	28.50	27.90	33.60	27.66
For comparing:		S.Em±		CD at 5%				S.Em±		CD at 5%		
S		0.378		1.096				0.541		1.567		
N		0.488		1.415				0.698		2.023		
SxN		0.845		2.450				1.209		3.504		

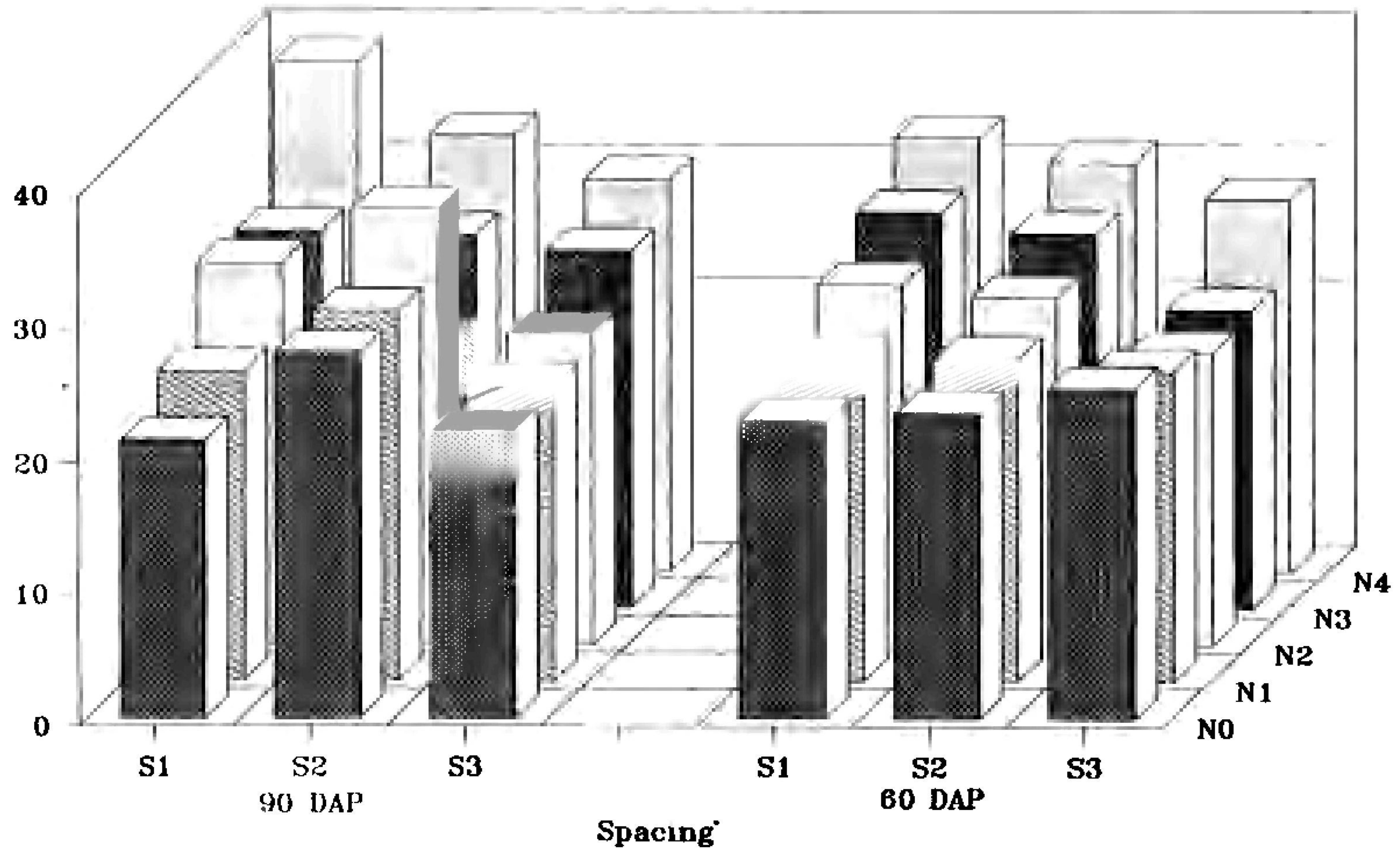


Fig. 5. Influence of plant density and nitrogen on length of flower stalk (cm) at 60 and 90 DAP in golden rod

4.2.5 Number of stalks per plot

The data on mean number of stalks per plot are presented in Table 11.

The flower stalk number per plot was influenced significantly by different spacing levels. The plots with high density (84 plants/plot) of plants gave the highest number of stalks (90.43), which was significant over the other two low plant density plots. The least number of stalks (50.47) were recorded in low plant density plots (42 plants/plot). The stalk number per plot was also significantly influenced by different nitrogen levels and was found to be highest (70.61) in highest level of nitrogen (N_4). However, this was found to be on par with N_3 (69.39 stalks per plot). The least (67.1) number of stalks were recorded in plants which were not applied with any nitrogen.

The interaction effect between spacing and nitrogen levels were found not significant. However, the combination S_1N_4 produced maximum (93.17) number of stalks per plot, while minimum (47.17) number of stalks per plot were recorded in treatment combination S_3N_0.

4.2.6 Yield per hectare (kg)

The data concerned to the yield per hectare are presented in Table 12.

The yield per hectare of golden rod was significantly influenced by different spacing levels. The highest yield of 8713 kg per hectare was recorded in close spacing (S_1) and was differed significantly over other wider spaced treatments. The yield was least (5000 kg per hectare) in widest spacing (S_3).

Table 11. Effect of plant density and nitrogen on number of stalks per plant at 90 DAP in golden rod

Treatmen	N_0	N_1	N_2	N_3	N_4	Mean
S_1	87.967	89.000	90.500	91.500	93.167	96.427
S_2	66.167	63.667	62.333	65.333	65.333	64.567
S_3	47.167	49.167	51.333	51.333	53.333	50.467
Mean	67.100	67.278	68.056	69.389	70.611	68.487

For comparing:	S.Em±	CD at 5%
S	0.531	1.530
N	0.685	1.986
SxN	1.187	NS

Table 12. Effect of plant density and nitrogen on flower yield (kg/ha) in golden rod

Treatmen	N_0	N_1	N_2	N_3	N_4	Mean
S_1	8524.56	8641.90	9734.44	9788.67	8876.17	8713.15
S_2	5930.67	6211.97	6252.60	6341.56	6369.73	6221.30
S_3	4780.73	4878.50	4920.91	5107.52	5313.19	5000.25
Mean	6411.99	6577.46	6635.98	6746.05	6853.03	6644.90

For comparing:	S.Em±	CD at 5%
S	24.384	70.672
N	31.480	91.237
SxN	54.525	NS

The nitrogen levels had significant effect on yield per hectare. The maximum flower yield (6853 kg per hectare) was observed in the highest nitrogen (N_4) level and this was significant over all other lower nitrogen levels. The flower yield was least (642 kg per hectare) in which no nitrogen was applied and few was significantly lower than all other treatments with different levels of nitrogen.

The interaction effects were not-significant. However, maximum (9789 kg per hectare) yield was recorded in treatment combination S_1N_3 followed by S_1N_2 (9734 kg per hectare). The yield per hectare was least in the treatment combination S_3N_0 (4781 kg per hectare).

4.2.7 Correlation studies

Correlation studies were made between the yield and spacing. The spacing recorded the negatively significant correlation with yield of golden rod (Table 13). The spacing influence the yield of golden rod to the extent of 91 per cent. But positively non-significant correlation was observed between fertilizer and yield.

4.2.8 Economics

The cost of cultivation of golden rod as influenced by plant population and nitrogen is given in Appendix III.

The maximum net profit at Rs. 11451.75 per hectare was obtained with the treatment combination S_1N_0 followed by Rs. 11016.75 per hectare with S_1N_1 and Rs. 10581.75 per hectare with the combination S_1N_2. The least net profit was Rs. 1681 per hectare with the treatment combination S_3N_4.

Table 13. Influence of spacing and fertilizer on yield of golden rod

Factors	Yield (kg/ha)	
	'r'	100 x r^2
Fertiliser	0.111	1.23
Spacing	−0.954	91.01

4.3 VASE LIFE

4.3.1 VASE LIFE (DAYS)

The vase life of golden rod stalks kept in different chemical preservatives showed significant differences which are presented in Table 14, Plate 5 and Fig. 6.

The flower kept in $Al_2 (SO_4)_3$ at 0.4 per cent lasted significantly longer (9.27 days) followed by those kept in $AgNO_3$ at 0.03 per cent (8.40 days). Though the vase life of flowers kept in sucrose at 0.2 per cent (7.60 days) and $Al_2(SO_4)_3$ at 0.2 per cent (7.00 days) was on par with each other, they were significantly higher than those kept in sucrose 0.1 per cent and tap water. The flowers kept in tap water lasted least (5.4) days in vase.

Table 14. Influence of different chemical treatment on vase life (days) of golden rod

Treatments	Vase life (days)
1. Tap water	5.47
2. Sucrose 0.1%	6.47
3. Sucrose 0.2%	7.60
4. $AgNO_3$ 0.02%	7.30
5. $AgNO_3$ 0.03%	8.40
6. $Al_2 (SO_4)_3$ 0.2%	7.00
7. $Al_2 (SO_4)_3$ 0.4%	9.27
S.Em ±	0.16
CD at 5%	0.49
CD at 1%	0.67

Plate 5. Vase life of golden rod stalk in different chemical preservatives

LEGEND

1. Tap water (Control)
2. Sucrose 0.1%
3. Sucrose 0.2%
4. $AgNO_3$ 0.02%
5. $AgNO_3$ 0.03%
6. $Al_2(SO_4)_3$ 0.2%
7. $Al_2(SO_4)_3$ 0.4%

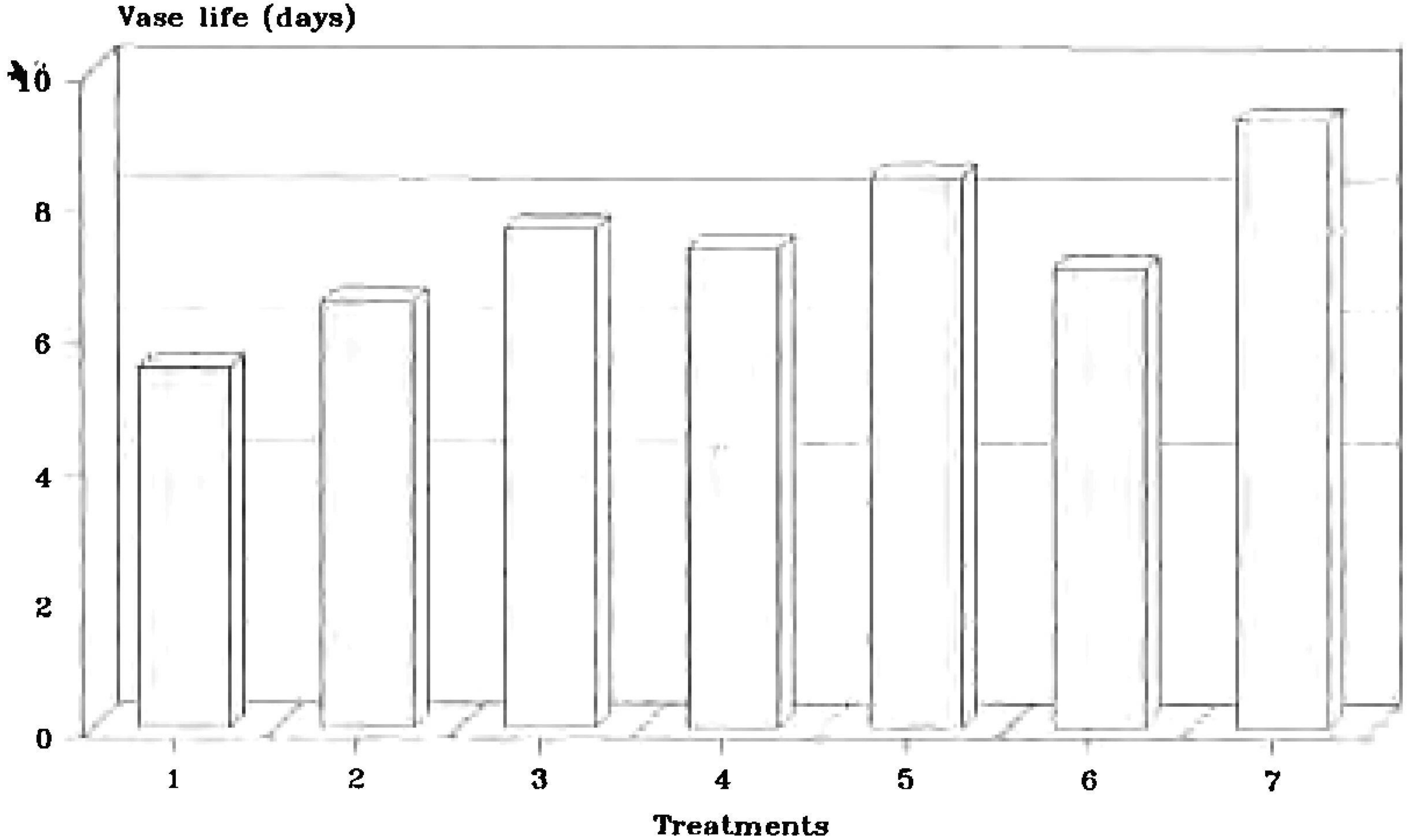


Fig. 6. Influence of different chemical treatments on vase life (days) of golden rod

Discussion

V. DISCUSSION

Cut flowers like roses, chrysanthemums, gladiolus, tuberose, orchids and anthuriums have attained international importance and being cultivated on commercial scale with sophisticated technology. There are few others like aster, marigold, gaillardia and golden rod which are being cultivated in a restricted and localised areas. Out of these, marigold, aster and gaillardia received attention of research workers (Maheshwar, 1977; Ingawale, 1979; Nalawadi, 1982; Mantur, 1988; Mokashi, 1988 and Vijayakumar, K.T., 1989), while, very little information is available on the production technology of golden rod. The factors responsible for economic yield in a crop are genotypes, climate, soil, cultural manipulations and their interactions. In addition to these factors, plant density (plant population) and mineral nutrition also play a vital role in growth and yield of any crop plant.

The present investigation was undertaken to know the suitable inter-row spacing (plant density) and optimum nitrogen requirement and their effect on flower yield of golden rod. The results of the present investigation are discussed in this chapter.

5.1 EFFECT OF PLANT POPULATION

The golden rod plants planted at closer spacing (45x20cm) recorded maximum flower yield of 8.71 tonnes per hectare which was significantly higher over other plant densities. The increase in yield at the highest density (1,11101 plants per hectare) was 28.6 per cent more than the plant density of 74074 plants per hectare and 42.6 per cent more than the plant density at 555558 plants per hectare. This is a significant outcome with least input expenditure. Though there was no significant difference in the number of flower stalks per plant at different plant densities, yield per unit area differed significantly. The yield was higher in closely spaced plants, and the quality of flower as indicated by length of flower stalk was superior in highest plant density. Vijayakumar (1989) observed the similar trend of increase in the flower yield per hectare due to higher plant density. Like other cutflowers, length of flower stalk is an important quality parameter in golden rod. Higher densities have increased the length of flower stalks. This may be due to the competition between the plants (Yadav *et al.*, 1985)

The higher plant density has improved both quality and yield per unit area. Although, the plants spaced wider could develop significantly like higher canopy spread over other spacings, but were inefficient to trap all the incoming radiation. The plants at higher density level utilised full space to grow taller and produced more number of leaves. This helped in increasing photosynthetic efficiency, accumulation of more dry matter and production of more number of flowers, and thus final yield per unit area. Arora and Saini (1976) obtained higher yield per unit area in closely spaced aster plants. Vijayakumar (1989) recorded decrease in the quality of aster at closer spacing which is in contrast to the results obtained in the present study. In aster, quality is the size of flowers, whereas in golden rod it is the length of the flower stalk. Mokashi (1988) reported that the increase in yield at closer spacing was also due to competition to grow better. The attributing characters towards yield, such as leaf area, total dry matter and plant height were found to increase with increase in plant population which could have contributed to maximum yield in densely populated crop.

5.2 EFFECT OF NITROGEN

The overall improvement in growth parameters, flower yield and flower quality in many of the flowering annuals is the resultant of judicious and balanced use of nutrients (Elengovan 1975 and Mantrova *et al.*, 1976). An interruption in plant nutrition even for a shorter period has a negative effect on yield (Gruise and Joiner 1961). Nitrogen is the most vital element among the major nutrient elements essentially required for commercial production of flowers. Among the nutrient elements, N is the most mobile element absorbed by the plant (Raheja 1966).

The results obtained from the investigation indicated that the application of nitrogen increased the flower yield. The increase in yield due to nitrogen application could be related to higher fresh and dry weights and length of flower stalks which significantly differed with increased levels of nitrogen. Highest yield was with highest nitrogen level of 100 kg per ha. The results obtained are in confirmity with that of Vijayakumar (1989) in aster and Yadav *et al.* (1985) in rose. The difference in flower yield and size of flower stalk due to nitrogen application could be related to difference in the plant characters.

The plant canopy increased with an increase in the levels of nitrogen and the maximum was in 100 kg N per ha.The dry matter production per plant also increased at higher levels of nitrogen. The higher dry matter production was due to more number of leaves per plant, plant height and leaf area. Thus nitrogen has helped the plants to utilise light and other resources more efficiently and to produce more photosynthates, which inturn contributed for the production of more flowers, and increasing the stalk length. Similar results have been obtained by Joiner and Smith (1960) and Vijayakumar (1989). However, flowering was delayed at higher levels of nitrogen as evidenced by the time taken to 50 per cent flowering. This may be due to the role of nitrogen in enhancing vegetative growth and delaying flowering. These results are in similarity with the findings of Vijayakumar (1989).

5.3 EFFECT OF INTERACTION OF PLANT POPULATION AND NITROGEN LEVELS

It is well known that improving the conditions for growth by altering or trying different combinations of one factor with the other can promote better yield in crops under a definite set of environmental conditions. It is still important to know which growth factor is limiting in relation to a definite set of combinations of factors in order to arrive at a conclusive explanation to suggest the best one to adopt the cultivation of ornamentals such as golden rod. In this context, discussing the interaction effects between different plant populations and nitrogen levels becomes more important since, the best yields are obtained under the influence of appropriate combination.

In the present investigation, though there were significant differences in yield due to individual effect of nitrogen and density, they failed to show significant variation due to their combination. However, significant difference due to interaction between plant density and nitrogen levels was observed for parameters like, plant height, number of leaves, leaf area, dry weight, number of days for 50 per cent flowering and length of flower stalk. Similar results wherein interaction effects due to plant density and nitrogen level were significant for some of yield contributing characters without significantly influencing yield was observed by Venugopala (1991). He could not get any significant interaction effect between spacing and nitrogen levels. But, Mokashi (1988) and Vijayakumar (1989) reported significant results in aster and gaillardia, respectively.

5.4 CORRELATION STUDY

The values indicate positive non-significant correlation between yield and nutrition indicating increase in fertilizer level will not bring much increase in the yield of spikes of golden rod.

However, yield and spacing levels are negatively related. So increasing the spacing will reduce the yield of golden rod spikes.

5.5 ECONOMICS

The economic analysis (Appendix III) revealed that the combination of factors S_1N_0 recorded the maximum net returns (Rs. 11,451.75 per hectare). This is because it has recorded the maximum flower spike yield per hectare.

5.6 VASE LIFE

The results obtained in vase life studies of golden rod indicated the superiority of chemical preservatives in prolonging the keeping quality of cutflowers over water. The increased vase life of cut flowers in the chemical presevatives like $Al_2(SO_4)_3$ at 0.4 per cent and $AgNO_3$ at 0.03 per cent could be attributed to the improved water uptake, reduction in transpiration, lowering of pH in the petal, stabilization of anthocyanin acidification of holding water, reducing bacterial growth and blocking of vascular bundles. The maximum vase life of flowers was observed in the present study with 0.4 per cent $Al_2(SO_4)_3$ (9.2 days) followed by 0.03 per cent $AgNO_3$ (8.4 days). The vase life of flowers in water was lowest (5.5 days) and these results are in line with the work of Vijayakumar (1989) and Gowda (1986) in aster, Kofranek *et al.* (1975) in chrysanthemum.

FUTURE LINE OF WORK

In the light of outcome gained with this investigation, the following future line of work is suggested.

1) Since golden rod is a long duration crop, studies on split application of nutrients may be tried.

2) As there was increasing response for highest levels of nitrogen, i.e., 100 kg per hectare still higher doses may be tried.

3) Since golden rod showed response to highest plant density without affecting the quality of flower stalks even higher densities may be tried.

4) Additional chemicals may be tried to prolong the vase life of golden rod.

5) Studies on other operation like pinching, use of growth regulators in combination with plant density may be carried out.

Summary

VI. SUMMARY

A field Experiment was carried out in the Floriculture Unit of University of Agricultural sciences, College of Agriculture, Dharwad during 1993-94 to find out the effect of plant density and nitrogen levels on growth and yield of golden rod (*Solidago canadensis* Linn.) The results of this investigation are summerised here under.

1) The flower yield of golden rod increased significantly with an increase in the Plant density. The maximum mean yield of 8.7 tonnes per hectare was obtained when the plants were spaced at 45x20 cm (closer spacing).

2) Golden rod responded very well to the higher levels of nitrogen. The yield increased significantly with the increased levels of nitrogen. The highest level of nitrogen (100 kg per hectare) recorded the maximum yield of 6.9 tonnes per hectare over all population.

3) The interaction effect between spacing and nitrogen levels was insignificant with respect to flower yield. However, the highest yield of 9.8 tonnes per hectare was obtained by treatment combination of 45x20 cm spacing and 75 kg nitrogen per hectare (S_1N_3).

4) The plants planted at closer spacing (45x20cm) and supplied with maximum nitrogen fertilizer (100 kg per hectare) level had significant influence on superior quality of flowers which is indicated by the production of flowers with more stalk length.

5) The maximum vase life of golden rod flowers was recorded with $Al_2(SO_4)_3$ 0.4 percent (9.2 days) followed by $AgNO_3$ at 0.03 percent (8.4 days). The flowers kept in water had the lowest vase life of 5.5 days.

6) Cultivation of golden rod was found to be economical with a net return of Rs. 11450 per hectare.

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Appendices

Appendix I. Monthly meteorological data for the year 1993 - 1994 and average of 43 years (1950-1993) of the Main Research Station, UAS, Dharwad

Months	Rainfall (mm)			Temperature (°C)						Relative humidity (%)		
				Mean maximum			Mean minimum					
	1993	1994	1950-94	1993	1994	1950-94	1993	1994	1950-94	1993	1994	1950-94
January	0.0	8.0	0.6	30.1	29.3	29.3	13.7	14.5	13.6	80.0	81.0	60.4
February	0.0	0.0	0.0	31.7	31.9	34.2	14.8	16.2	15.3	76.0	76.0	53.8
March	0.0	0.0	6.4	34.5	36.1	35.0	18.8	20.0	18.3	70.0	68.0	54.7
April	16.2	53.6	51.7	37.1	34.9	36.3	20.5	20.6	20.4	66.0	70.0	58.7
May	107.7	28.0	92.6	36.2	36.5	36.0	21.3	21.3	21.0	67.0	65.0	65.7
June	85.5	86.0	118.3	30.1	28.1	29.3	21.3	20.9	20.7	79.0	84.0	80.2
July	166.0	296.1	159.9	27.4	25.0	26.5	20.9	20.6	20.5	89.0	93.0	86.2
August	68.1	89.3	103.6	26.3	25.6	26.6	20.5	20.6	20.2	89.0	91.0	84.4
September	44.6	52.6	107.0	28.1	27.5	28.1	20.1	19.2	19.7	86.0	86.0	81.2
October	266.2	164.2	130.1	29.9	29.0	29.6	21.0	20.1	18.7	84.0	83.0	73.7
November	8.4	-	34.6	28.9	-	28.7	17.3	-	15.9	82.0	-	65.2
December	39.6	-	3.3	26.7	-	18.6	13.7	-	13.6	86.0	-	61.1

Appendix II. Prices of inputs and outputs

Inputs	Price (Rs.)
1. Suckers of golden rod	0.10 ps. each
2. Urea	8000.00 per t
3. Single super phosphate	115000.00 per t
4. Muriate of potash	2400.00 per t
5. Man labour	35.00 per day
6. Women labour	25.00 per day
7. Bullock pair	100.00 per day
8. Land rent	300.00 per ha

Appendix III. Details of the cost of cultivation of golden rod (Rs/ha)

Treatments	S_1N_0	S_1N_1	S_1N_2	S_1N_3	S_1N_4	S_2N_0	S_2N_1	S_2N_2	S_2N_3	S_2N_4	S_3N_0	S_3N_1	S_3N_2	S_3N_3	S_3N_4
Details															
1. Land preparation (Ploughing, harrowing and transplanting)	505	505	505	505	505	420	420	420	420	420	395	395	395	395	395
2. Fertilizer and sucker cost	14904	15339	15774	16209	16644	11201	11636	12071	12505	12940	9349	9784	10219	10654	11088
3. Fertilizers application	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
4. Intercultivation and weeding	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
5. Land rent	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
6. Harvesting	250	250	250	250	250	175	175	175	175	175	100	100	100	100	100
7. Transport and marketing costs	90	90	90	90	90	70	70	70	70	70	50	50	50	50	50
Total costs	16324	16759	17194	17629	18064	12441	12876	13311	13745	14180	10469	10904	11339	11774	12208
Gross returns	27775.75	27775.75	27775.75	27775.75	27775.75	18518.50	18518.50	18518.50	18518.50	18518.50	13889.00	13889.00	13889.00	13889.00	13889.00
Net returns	11451.75	11016.75	10581.75	10146.75	9711.75	6077.50	5642.50	5207.50	4773.50	4338.50	3420.00	2985.00	2550.00	2115.00	1681.00