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Effect of varying rates of nitrogen fertilization on crop yield, soil properties and plant nutrient uptake by gaillardia (*Gaillardia pulchella* L.) cv. MG-9- 1

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ABSTRACT

Gaillardia flowers have the potential to replace the traditional loose flowers of marigold and chrysanthemum. The present study was conducted to determine the optimum dose of nitrogen for higher flower production and to maintain the sustainability of soil health. Seven different levels of nitrogen (0, 50, 150, 200, 250 and 300 kg ha^{-1}) with a fixed dosage of phosphorous and potassium (80 kg ha^{-1}) were applied to the soil of the experimental plots. The results demonstrated that the economical yield of the crop did not increase beyond the application of nitrogen @ 200 kg ha^{-1}. Thus, for obtaining the maximum flower yield of gaillardia, a nitrogen dosage of 200 kg ha^{-1} is recommended. The findings of the present study would help in maximizing the returns to the farmers by minimizing the input cost of nitrogenous fertilizers. Moreover, it would help in sustaining soil health by ensuring the application of the optimum dosage of nitrogenous fertilizers.

Keywords: Gaillardia; nitrogen application rate; flower yield; soil properties; nutrient uptake

INTRODUCTION

Gaillardia (*Gaillardia pulchella* L.), popularly known as the blanket flower and is native to the Central and Western United States. It is a member of the Asteraceae family and has 18 gametic and 36 somatic chromosomes. Gaillardia is characterized as a short-lived herbaceous crop (Helen *et al.,* 2007) with resilient flowering. It can be grown as an annual, biennial or perennial crop depending upon the climatic conditions of the area. In recent years, the crop is gaining importance owing to its year-round availability, low maintenance and greater resilience towards various biotic and abiotic stresses. Owing to this, the flower is widely grown in semi-arid, arid and tropical conditions for beautification and in landscaping as low-maintenance herbaceous borders and hedges. The showy bi-coloured or single hue flower finds its place as a loose flower for garlands and rangoli. The flowers can also be used as cut flowers in bouquets and vases when supplemented with floral preservatives.

The ultimate objective in profitable flower production is to enhance flower yield while maintaining quality and maintaining the sustainability of the agroecosystem. Gaillardia crop yield is heavily influenced by the availability of inherent soil nutrients and manurial schedule. For crop growth and yield nitrogen is an essential mineral (Xu *et al.,* 2012). During the past few decades application of nitrogenous fertilizers has rapidly increased to obtain higher. An excessive application of nitrogen typically raises input costs and makes the plants susceptible to various pests and foliar diseases in addition to the degradation of the quality of the soil attributes, overall crop health and contamination of groundwater (Guo *et al.,* 2010; Schroder *et al*., 2011). While, its deficiency results in declined stem length, leaf area, canopy photosynthesis, dry matter accumulation and leaf chlorophyll content (Bar-tal *et al.,* 2007, Zhao *et al.,* 2003, Kalaji *et al.,* 2014 and Zhao *et al.,* 2017). Even though many factors determine the optimal nitrogen rate, studies have shown that a minimal decrease in nitrogen inputs does not reduce crop output (Luo *et al.,* 2018), but rather increases nitrogen usage efficiency by the crop plants (Zhang *et al.,* 2015a). Optimum nitrogen fertilization approaches should be site-specific. Thus, to determine an optimal rate of nitrogen and its effect on soil properties and nutrient uptake, the present experiment was conducted with the objectives to determine the

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optimum dosage of nitrogen for the gaillardia crop and also to study the effect of different levels of nitrogen on the uptake of phosphorus and potassium.

MATERIALS AND METHODS

Plant materials and Experimental site

The experiment material comprised cultivar MG-9-1 being maintained at Phule Krishi Vidyapeeth, College of Agriculture, Shivajinagar, Pune, Maharashtra. The site is located at 559 m above mean sea level at 18.32^0 N latitude and 73.51^0 E longitude. Seeds of the cultivar were sown on flat seed-beds. Thirty-day-old healthy seedlings were transplanted at 60 × 45 cm in the *Kharif* season of 2019. The cultivar was evaluated phenotypically in a Randomized Complete Block Design with three replications comprising 24 plants in each block. Each block had a size of 2.4 m × 2.7 m.

Details of the Treatments

The experiment was comprised of seven treatments with varying levels of nitrogen and a constant dose of phosphorous and potassium (Table 1). Across the treatments, nitrogen, phosphorus and potassium were applied in the form of urea, single super phosphate and muriate of potash, respectively. The calculated nitrogen for each treatment was applied @ 40% as basal dose and the remaining 60% was applied in two equal splits 60 and 120 days after transplanting. The dose of 80 kg each of phosphorus and potassium per hectare was applied in two equal splits, the first half as basal dose and the remaining half at 60 days after transplanting.

Table1: Details of different dosage of nitrogen (N), phosphorus (P) and potassium (K) applied in the current experiment

Treatment	Treatment Details N: P: K (kg/ha)
T_1	0:80:80
T_2	50:80:80
T_3	100:80:80
T_4	150:80:80
T_5	200:80:80
T_6	250:80:80
T_7	300:80:80

Soil sampling and analysis

Before laying and after completion of the trials, soil samples were collected for the assessment of different physicochemical properties as well as the nutrient status of the soil. Soil samples were collected with the help of an auger from a depth of 20 cm. Samples were taken from three cores within each plot and from each treatment separately. The collected samples were mixed thoroughly and sieved using a 2-mm mesh. The soil samples were then dried in the shade for further analysis. The available nitrogen, phosphorous and potassium in the soil were estimated following the standard alkaline potassium permanganate method (Subbiah and Asija, 1956), sodium bi-carbonate method (Olsen *et al*,1954) and Flame photometer (Black, 1965), respectively. Available organic carbon and calcium carbonate were estimated by the standard procedure of rapid titration (Jackson, 1973) and Walkey and Blacks method (Jackson, 1967), respectively.

Leaf Sampling, Nutrient Analysis and Estimation of Yield

To estimate the uptake of nitrogen, phosphorus and potassium by the plants, fresh upper and the middle-upper expanded leaves were collected from the primary branches of the plants from each replication in each treatment were collected. The leaves were cleaned before being dried in a hot-air oven at 65°C for one hour. The dried leaves were then crushed into a fine powder using a mortar and pestle. Standard techniques were followed to digest the powdered leaf samples with di-acid for the estimation of total phosphorus and potassium content. Potassium was estimated using a Flame photometer technique (Black, 1965), while phosphorus was estimated using the Vanado-molybdate yellow colour method (Watanbe and Olsen, 1956). Kjeldahl distillation and sulphuric acid digestion method were followed to determine the total nitrogen content of leaves (Tandon, 1993). Harvesting of flowers were carried out from each plot and the data were recorded. Based on the total plot yield, yield per hectare was calculated and expressed in tonnes.

Table 2: Basic soil properties of soil in the experimental plot before the experiment

Determination	Unit	Value obtained
E.C	dSm^{-1}	8.56
pH	-	0.27
Nitrogen	kg ha^{-1}	175
Phosphorus	kg ha^{-1}	48
Potassium	kg ha^{-1}	528
Organic Carbon	%	1.02
Calcium Carbonate	%	5
Sand: Silt: Clay	%	32.5: 30: 37.5

Statistical analysis

The obtained data were subjected to analysis of variance by employing a Randomized Complete Block Design along with a significance test (F test) at a five percent level of significance ($P \leq 0.05$) to examine the difference among the treatments. The correlation of the different treatments with the nutrient uptake and yield was also worked out. All the statistical analysis was performed by 'R' software version 1.1.0 for Windows.

RESULTS AND DISCUSSION

Effects of different dosages on different physico-chemical properties of soil

Across the treatments, significant variations were observed concerning different physicochemical properties of the soil of the experimental plots (Table 3). With the application of a variable quantity of nitrogen, the pH of the soil did not change considerably. It ranged from 7.71 (T_1) to 8.27 (T_7) among the various treatments. The possible reason for the non-significant results of soil pH could be the buffering capacity of the soil. To bring significant changes in the soil pH, alterations in the buffering capacity of the soil need to be done, which is a long-time process. Additionally, there was non-significant variation between the treatments in terms of changes in the electrical conductivity of the soil. The earlier report on carnation also suggests that the application of different dosages of nitrogen, phosphorus and potassium did not significantly change the soil electrical conductivity (Singh, 2011). However, contrary results to the present finding were observed in anthurium where the authors recorded a significant difference in soil reaction with varying levels of nitrogen (Das *et al.,* 2012). Further, the levels of soil organic carbon gradually increased with the increasing levels of nitrogen ranging from 0.37% (T_1) to 0.49% (T_6). Carbon being the primary component of soil organic matter, it has a strong correlation with soil nitrogen levels.

Effect of different nitrogen levels on the nutrient status of soil

Nitrogen availability in the soil increased with the increasing order of the treatments. The levels of available nitrogen in the soil varied significantly among the treatments and ranged from 101.61 kg/ha (T_1) to 214.50 kg/ha (T_7) (Table. 3). The possible reason for the increased levels of nitrogen in the soil is due to the role of soil microbes which through nitrification helps in the conversion of ammonium (NH_4^+) ions to nitrate (NO_3^-) ions. NO_3^- functions as a signalling molecule during the active growth of the plant (Bellegarde *et al.,* 2015 and Fredes *et al.,* 2019). Thus, a higher dose of nitrogen increases the overall growth and development of the plants.

Nitrogen application increases root growth and scavenging capacity of phosphorous, thus having a promotive effect on the bioavailability of soil P (Smith *et al.,* 1987; Zhou *et al.,* 2013; Emnova *et al.,* 2014; Valadares *et al.,* 2017; Zhang *et al.,* 2018). As the application of nitrogen affects plant metabolism and thus manipulates the ability of unit areas of the root surface to absorb phosphorous. Quite a lot of studies have shown that nitrogen application can upsurge phosphorous mobility in the rhizosphere (Apthorp *et al.,* 1987; Peng *et al.,* 2011). In the Inner Mongolia grassland, nitrogen deposition was found to alter soil P uptake (Zhang *et al.,* 2012). Potassium is known to play a vital role in nitrogen metabolism. Similarly, as the root zone expanded, the availability of potash in the soil significantly increased with increasing nitrogen fertilization. The available potassium in the soil from all the treatments exhibited an increasing trend with an increasing nitrogen rate. Earlier studies on gaillardia (Karetha *et al.,* 2011 and Paghdar, 2013), chrysanthemum (Joshi, 2005) and China aster (Badole *et al.,* 2015) also depicted that with the increase in the application of nitrogen in the soil, the availability of potassium content also increases.

Table 3: Effect of different levels of nitrogen on available Nitrogen (N), Phosphorus (P) and Potassium (K), organic carbon and Calcium Carbonate ($CaCO_3$) in the soil after harvest of the crop

Treatments	pH	EC	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	$CaCO_3$ (%)	Organic carbon (%)
T_1	7.71	0.19	101.61	40.55	388.64	1.50	0.37
T_2	7.90	0.20	130.65	42.87	390.66	1.50	0.41
T_3	8.25	0.20	158.06	43.50	393.12	1.50	0.43
T_4	8.25	0.20	165.02	43.50	476.00	1.60	0.43
T_5	8.20	0.18	169.35	43.80	486.08	1.50	0.44
T_6	8.22	0.19	180.64	44.02	614.88	1.50	0.49
T_7	8.27	0.20	214.5	44.40	661.91	1.50	0.48
S.E. (m)±	0.07	0.03	3.64	0.44	6.56	0.17	0
C.D. at 5%	0.22	NS	11.21	1.36	20.21	NS	NS

SE (m): Standard Error of Mean, CD: Critical Difference, NS: Non-significant at 5% level of significance

Effect of different dosages of nitrogen on the total nutrient uptake by the plants

The nutrient content in the leaves was significantly impacted by the varying levels of nitrogen in the soil (Table 5). Nitrogen levels exerted a significant impact on nitrogen content in the leaves. With increasing the levels of application, there was a significant increase in nitrogen concentration and total nitrogen uptake. Nitrogen concentration in the leaves ranged from 1.26 % (T_1) to 2.52 % (T_7). The treatment T_7, recorded nitrogen uptake (830.74 kg/ha) which was significantly higher when compared to all other treatments. Due to the increased root and shoot growth, the amount of foliage increases. Also, the photosynthetic activity and the cell formation process enhance which leads to the enhanced dry matter content of the plants.

Further, there was a significant increase in phosphorus concentration ranging from 0.60 % (T_1 and T_2) to 0.73 % (T_6 and T_7). Increased phosphorus availability attributable to nitrogen application might well have encouraged root growth in terms of root surface area and volume, favouring phosphorus absorption through roots and subsequent translocation in shoots. The treatment T_6 recorded a maximum uptake of phosphorus (282.72 kg/ha) among all the treatments. Significant variation was observed in the uptake of potassium by the plants ranging from 0.70% (T_3) to 0.98% (T_5). The treatment T_6 recorded a maximum potassium uptake (343.52 kg/ha) than the rest of the treatments. In gaillardia (Karetha *et al.,* 2011. Hugar and Nalawadi, 1998 and Gadagi *et al.,* 2004), China aster (Sonawane *et al.,* 2009, marigold (Ghosh and Pal, 2010 and Naik, 2015) and chrysanthemum (Joshi, 2005 and Dorajeerao, 2010) authors have found similar results, where the nutrient uptake by leaves was positively associated with the application of fertilizers in the soil.

Correlation of treatments on the uptake of nutrients and yield of flowers

The varying levels of nitrogen treatments were positively correlated with nitrogen uptake and phosphorous uptake (Table 2). The different nitrogen treatments were found to be significant and positively correlated with the nitrogen and phosphorous and potassium uptake by the leaves of the plant (r= 0.947 and 0.805, respectively). Further, the nitrogen uptake was also found to be positively correlated with phosphorous and potassium uptake by the leaves with a correlation coefficient of 0.894 and 0.765 at $p \le 0.01$ and $p \le 0.05$ respectively. Similar results were recorded in eucalyptus (Godoi *et al.,* 2021) and banana (Sun *et al.,* 2020) where an increase in the nitrogen doses augmented the plant biomass which increased the concentration of both phosphorous and potassium in the soil and plants.

Table 4: Correlation among the treatments and the uptake of the nutrients and yield of gaillardia flowers

	Nitrogen application (kg/ha)	N Uptake (kg/ha)	P Uptake (kg/ha)	K Uptake (kg/ha)	Yield of flowers (t/ha)
Nitrogen application (kg/ha)	1	0.947**	0.805*	0.679	0.598
N Uptake (kg/ha)		1	0.894**	0.765*	0.359
P Uptake (kg/ha)			1	0.893**	0.382
K Uptake kg/ha)				1	0.433
Yield of flowers (t/ha)					1

***Correlation is significant at 0.01 level (two tailed), * Correlation is significant at 0.05 level (two tailed)*

Effect of different dosages of nitrogen on the yield of flowers

The application of various levels of nitrogen under study resulted in appreciable changes in the number of flowers produced per plot and yield per hectare. The treatment T_5 recorded the highest flower production (22.67 t/ha) of the treatments under study. However, the treatment T_6 was found to be statistically on par with T_5. After achieving the maximum yield, however, crop yields can choose to remain the same or decline with additional increases in nitrogen rates. The considerable variance in flower output per hectare observed between treatments may be attributed to the number of flowers, flower yield per plant, differences in the response of the genotype towards the applied nutrients and prevailing environmental factors. Nitrogen application improves cell division which results in significant vegetative growth and also aids in the production and transit of cytokinin to the shoots (Wagner and Michael, 1971), which in turn leads to the development of a greater number of branches. The increased branches act as a reservoir for the production of a greater number of branches per plant. Subedi *et al.* (2020) in marigold, Kanesh (2005), Sowmyamala *et al.* (2013), Moon (2014), in their studies observed that the nitrogen dose up to 150 kg ha^{-1}, while Gawade *et al.* (2016), Salve (2017) in gaillardia, Tembhare *et al.* (2014) in China aster observed that 200 kg of nitrogen per hectare and Adhikari *et al.* (2020) in marigold recorded that application of nitrogen at 180 kg ha^{-1} significantly had higher flower yield.

Table 5: Effect of different levels of nitrogen on the total concentration and uptake of N, P, K and flower yield at the last harvest of the crop

Treatments	N %	N Uptake (kg/ha)	P %	P Uptake (kg/ha)	K %	K Uptake (kg/ha)	Yield of flowers (t ha^{-1})
T_1	1.26	364.94	0.60	181.21	0.87	250.37	13.879
T_2	1.28	387.78	0.60	182.96	0.75	226.69	14.9
T_3	1.50	438.89	0.64	188.15	0.70	203.83	16.698
T_4	1.65	494.07	0.66	196.98	0.75	225.00	18.75
T_5	1.85	533.48	0.71	204.15	0.98	282.22	22.67
T_6	1.95	759.75	0.73	282.72	0.88	343.52	19.372
T_7	2.52	830.74	0.73	239.48	0.87	286.80	16.596
SE (m) ±	0.03	8.73	0.02	3.01	0.01	2.63	12.03
C.D. at 5%	0.09	26.9	0.05	9.29	0.04	8.1	37.90

SE (m): Standard Error of Mean, CD: Critical Difference, NS: Non-significant at 5% level of significance

CONCLUSION

The present study demonstrated that nitrogen application had great impacts on soil properties and nutrient uptake. Excessive nitrogen application, other that the build-up in the soil had no significant role in increasing the crop yield. When considering the flower yield, physicochemical conditions and soil fertility, the recommended optimal nitrogen application rate is 200 kg per hectare along with constant dose of phosphorous and potassium @ 80 kg each per hectare.

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