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EFFECT OF NITROGEN, PHOSPHORUS AND POTASSIUM ON FLOWER PARAMETERS OF GOLDEN ROD (*SOLIDAGO CANADENSIS* L.)

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ABSTRACT

A study was conducted at College of Horticulture, Venkataramannagudem to analyze the effect of nitrogen, phosphorus and potassium on growth, yield and quality of golden rod under local agro-climatic conditions. The three major nutrients *viz.*, nitrogen (75, 150 and 225 kg ha^{-1}), phosphorus (75, 150 and 225 kg ha^{-1}) and potassium (50, 100 and 150 kg ha^{-1}) were applied each at three levels in a 3^3 factorial design, making twenty seven treatment combinations replicated twice. In the present study the earliest flowering was observed by the application of lower dose of nitrogen i.e. 75 kg ha^{-1}. There was significant delay in the higher doses *i.e.* 150 and 225 kg ha^{-1} of nitrogen. Significant differences were noticed with respect to number of panicles per ha^{-1} among the different levels of nitrogen, phosphorus, potassium and their interactions. The highest number of panicles per ha (1.94 lakhs) was registered by the highest dose of nitrogen N3-225 kg ha^{-1} on par with N_2-150 kg ha^{-1} (1.92 lakhs) among nitrogen levels whereas, P_3 registered best value (1.90 lakhs) on par with P_2-150 kg ha^{-1} (1.87 lakhs) among phosphorus levels. Among the potassium levels K_3-150 kg ha^{-1} recorded maximum value (1.91 lakhs) and was on par with K_2-100 kg ha^{-1} (1.85 lakhs). Among the interactions, maximum number of panicles per ha^{-1} (1.99) was recorded by the combination of $N_3P_3K_3$ (225+225+150 kg ha^{-1}) which were significantly superior to $N_1P_1K_1$ (75+75+50 kg ha^{-1}) (1.45). The combinations of $N_3P_3K_3$ (225+225+150) kg ha^{-1} and $N_2P_2K_2$ (150+150+100 kg ha^{-1}) were showing on par results with respect to a majority of quality parameters *viz.*, length of inflorescence, number of primary branches, vase life and longevity. The highest benefit cost ratio (3.13) was recorded by the combination of $N_2P_1K_3$ (150+75+150 kg ha^{-1}). However, it could be summarily concluded that application of NPK at the rate of 225+225+150 kg ha^{-1} was found to give best results in all the vegetative and reproductive parameters which was found on par with combination of NPK at the rate of 150+150+100 kg ha^{-1} in most of the growth and flower parameters.

***Key words*: NPK, Fertilizers, Golden Rod, Growth, Yield, Quality.**

Introduction

Solidago, commonly known as golden rod, belongs to the family Asteraceae, botanically known as *Solidago canadensis* L. The genus comprises about 130 species, mostly native of North America. Few species like *Solidago canadensis*, S. *virgaurea*, S. *memoralis* are grown in beds borders or rock garden. Besides, they are also used as cut flowers for indoor decoration and bouquets. It produces large panicles of yellow flowers for several months a year, which are very attractive cut flowers. These hardy perennial herbs grown in almost all types of climates and soils but prefer a sunny location.

Golden rod plant is medium in height (about 20-30 cm tall) and has light green leaves. Plant is spreading by producing (multiplying) new suckers. Golden rod requires about 100 to 130 days for coming in the flowering stage after planting. It bears panicles of about 50-75 cm of length with 30-50 numbers of inflorescence branches per panicle. The inflorescence of golden rod is very complex in nature. Basically, each small head is about 1.0 to 1.2 cm in length and 0.5 to 0.7 cm in diameter and consists of about 8 to 10 disc florets and some ray florets. Heads are axillary, solitary on main axis as well as branches and on small branchlets forming a whole compound panicle with golden yellow inflorescence.

Golden rod is propagated by division of stools, from suckers or seeds. The plants are easy to grow. In moderate climate, planting can be done in any time but spring and rainy seasons are more favourable for growth. The commercial cultivation of golden rod has not yet been exploited in India. Even though golden rod is cultivated in small scale by many farmers, there is also a great demand of golden rod panicles in large cities of India and greater scope exists for its export for various purposes like bouquets and table decoration. Golden rod can be cultivated on all type of soils having good structure drainage with proper management practices. Among the different management practices, nutrient management plays an important role for good growth and flower production. The deficiency of nutrient in the soil is generally expressed in the form of certain disorders on the plant. The deficiency problems are particularly severe in light sandy soil which can be corrected by the additional supply of the particular nutrient to the plant. It has been observed that N, P, K and Fe nutrients are limiting factors in successful growing of golden rod. Thus, the response of golden rod to the applied nutrients is quite encouraging in term of flower (panicles) production. Considering this, the present investigation was planned to find out the influence of chemical fertilizers on growth and flower production of golden rod.

Materials and Methods

The present investigation entitled "Effect of nitrogen, phosphorus and potassium on growth yield and quality of golden rod (*Solidago canadensis* L.)" was carried out during the year 2017-2018 at College of Horticulture, Dr. Y.S.R. Horticultural University, Venkataramannagudem, West Godavari District. The experiment was laid out in 3^3 Factorial Randomised Block Design with two replications. Nitrogen was taken as first factor and phosphorus was taken as second factor and potassium was taken as third factor. Each of these factors was composed at three levels. The land was brought to a fine tilth by ploughing and harrowing. Plots were made with a gross size of 2.7 m × 1.4 m. A spacing of 100 cm between two replications and 50 cm between two plots within a replication was provided for laying out irrigation channel and working space. The suckers of golden rod with uniform size were taken and treated with Bavistin @ 2 g per litre of water for 10 minutes. Light irrigation was given immediately after planting. Well decomposed farm yard manure at the rate of 100 kg ha^{-1} was applied at the time of land preparation. The fertilizers viz., Urea, Single Super Phosphate and Muriate of Potash were taken as the sources of N, P_2O_5 and K_2O respectively. Entire dose of phosphorus and potassium was given basally and half dose of nitrogen was applied as per the treatment before planting and the remaining half dose was applied at 45 days after planting.

Treatment Combinations:

T_1	:	$N_1P_1K_1$	N@75kgha^{-1}	+	P@75kgha^{-1}	+	K@50kgha^{-1}
T_2	:	$N_1P_1K_2$	N@75kgha^{-1}	+	P@75kgha^{-1}	+	K@100kgha^{-1}
T_3	:	$N_1P_1K_3$	N@75kgha^{-1}	+	P@75kgha^{-1}	+	K@150kgha^{-1}
T_4	:	$N_1P_2K_1$	N@75kgha^{-1}	+	P@150kgha^{-1}	+	K@50kgha^{-1}
T_5	:	$N_1P_2K_2$	N@75kgha^{-1}	+	P@150kgha^{-1}	+	K@100kgha^{-1}
T_6	:	$N_1P_2K_3$	N@75kgha^{-1}	+	P@150kgha^{-1}	+	K@150kgha^{-1}
T_7	:	$N_1P_3K_1$	N@75kgha^{-1}	+	P@225kgha^{-1}	+	K@50kgha^{-1}
T_8	:	$N_1P_3K_2$	N@75kgha^{-1}	+	P@225kgha^{-1}	+	K@100kgha^{-1}
T_9	:	$N_1P_3K_3$	N@75kgha^{-1}	+	P@225kgha^{-1}	+	K@150kgha^{-1}
T_{10}	:	$N_2P_1K_1$	N@150kgha^{-1}	+	P@75kgha^{-1}	+	K@50kgha^{-1}
T_{11}	:	$N_2P_1K_2$	N@150kgha^{-1}	+	P@75kgha^{-1}	+	K@100kgha^{-1}
T_{12}	:	$N_2P_1K_3$	N@150kgha^{-1}	+	P@75kgha^{-1}	+	K@150kgha^{-1}
T_{13}	:	$N_2P_2K_1$	N@150kgha^{-1}	+	P@150kgha^{-1}	+	K@50kgha^{-1}
T_{14}	:	$N_2P_2K_2$	N@150kgha^{-1}	+	P@150kgha^{-1}	+	K@100kgha^{-1}
T_{15}	:	$N_2P_2K_3$	N@150kgha^{-1}	+	P@150kgha^{-1}	+	K@150kgha^{-1}
T_{16}	:	$N_2P_3K_1$	N@150kgha^{-1}	+	P@225kgha^{-1}	+	K@50kgha^{-1}
T_{17}	:	$N_2P_3K_2$	N@150kgha^{-1}	+	P@225kgha^{-1}	+	K@100kgha^{-1}
T_{18}	:	$N_2P_3K_3$	N@150kgha^{-1}	+	P@225kgha^{-1}	+	K@150kgha^{-1}
T_{19}	:	$N_3P_1K_1$	N@225kgha^{-1}	+	P@75kgha^{-1}	+	K@50kgha^{-1}
T_{20}	:	$N_3P_1K_2$	N@225kgha^{-1}	+	P@75kgha^{-1}	+	K@100kgha^{-1}
T_{21}	:	$N_3P_1K_3$	N@225kgha^{-1}	+	P@75kgha^{-1}	+	K@150kgha^{-1}
T_{22}	:	$N_3P_2K_1$	N@225kgha^{-1}	+	P@150kgha^{-1}	+	K@50kgha^{-1}
T_{23}	:	$N_3P_2K_2$	N@225kgha^{-1}	+	P@150kgha^{-1}	+	K@100kgha^{-1}
T_{24}	:	$N_3P_2K_3$	N@225kgha^{-1}	+	P@150kgha^{-1}	+	K@150kgha^{-1}
T_{25}	:	$N_3P_3K_1$	N@225kgha^{-1}	+	P@225kgha^{-1}	+	K@50kgha^{-1}
T_{26}	:	$N_3P_3K_2$	N@225kgha^{-1}	+	P@225kgha^{-1}	+	K@100kgha^{-1}
T_{27}	:	$N_3P_3K_3$	N@225kgha^{-1}	+	P@225kgha^{-1}	+	K@150kgha^{-1}

Observations Recorded

1. **Number of days taken for first Panicle emergence:** Number of days required for the emergence of first panicle from the day of planting was recorded in all the plots.
2. **Number of days taken for opening of first floret:** The number of days taken for opening of first floret from the day of panicle initiation in each tagged plant that received a particular treatment was recorded.

3. **Number of days taken for 50% flowering:** The number of days taken for 50 per cent of the plants in any plot that received a particular treatment to produce panicles was recorded.
4. **Number of days taken for complete flowering:** Number of days required for all the plants in plot to produce panicles from the day of planting was recorded in each plot and their mean was worked out.
5. **Length of inflorescence (cm):** Length of inflorescence was measured from the base of the inflorescence where the plagiotrophic branches with fully opened florets arise, to the top most floret located on the bloom.
6. **Number of primary branches per panicle:** The total number of primary branches on the inflorescence are counted on each of the tagged plants and recorded.
7. **Number of panicles per plot:** The yield per plot was obtained by counting the total number of panicles present in each net plot.
8. **Number of panicles ha^{-1} (lakh):** Number of panicles per ha^{-1} was estimated based on the yield of panicles per plot.
9. **Number of days taken for first harvest:** Number of days required for first harvesting of panicles from the day of planting was recorded in each plot that received a particular treatment.
10. ***In situ* longevity of flower panicles:** Number of days required from first floret emergence to drying of all florets was recorded as *in situ* longevity of flower panicles.

Fig. 1: General view of experimental field at 60 DAP.

11. **Vase life (days):** One fourth opened compound flower blooms having uniform thickness and of 40 cm length were selected randomly from each treatment and used for the study. Lower leaves were removed and one panicle was kept in 250 ml conical flask containing 200 ml distilled water. Number of days was counted till the day on which panicles were found unfit for continuing in the vase and recorded as vase life.

Results and Discussion

Number of days taken for first panicle initiation

It is evident from the tabulated data (Table 1) that the graded levels of nitrogen, phosphorus and potassium levels exerted significant influence on number of days taken for first panicle initiation. Among nitrogen levels, the first panicle initiation was at the earliest (53.44 days) in N_1-75 kg ha^{-1} followed by N_2 -150 kg ha^{-1} (54.80 days).

The minimum number of days taken for first panicle initiation (54.02days) was noticed in P_1 (75kg ha^{-1})

Table 1: Number of days taken for first panicle initiation as influenced by nitrogen, phosphorus, potassium and their interaction in golden rod.

Number of days taken to panicle initiation (days)					
N levels					
P levels	**K levels**	**N_1(75)**	**N_2(150)**	**N_3(225)**	**Mean**
P_1(75)	K_1(50)	53.16	54.23	54.26	**53.88**
	K_2(100)	53.2	54.33	54.38	**53.97**
	K_3(150)	53.23	54.68	54.69	**54.2**
	Mean	**53.2**	**54.41**	**54.44**	**54.02**
P_2(150)	K_1(50)	53.41	55.02	55.04	**54.25**
	K_2(100)	53.6	55.23	55.28	**54.6**
	K_3(150)	54.23	55.43	55.46	**54.87**
	Mean	**53.43**	**54.76**	**54.79**	**54.68**
P_3(225)	K_1(50)	53.4	54.98	54.99	**54.39**
	K_2(100)	53.64	55.12	55.16	**54.55**
	K_3(150)	53.72	55.23	55.26	**54.69**
	Mean	**53.47**	**54.86**	**54.89**	**54.57**
	For comparison between N and K levels				
	K_1(50)	53.32	54.74	54.76	***54.28***
	K_2(100)	53.48	54.89	54.94	***54.44***
	K_3(150)	53.73	55.11	55.14	***54.66***
	Mean	***53.44***	***54.8***	***54.83***	***54.35***
		SEm		**CD at 5%**	
N levels		0.16		0.46	
P levels		0.16		0.46	
K levels		0.16		0.46	
N × P		0.25		0.74	
P × K		0.25		0.74	
N × K		0.25		0.74	
N × P × K		0.4		1.17	

followed by P_2 -150kg ha^{-1} (54.68days) among phosphorus levels.

Among potassium levels minimum number of days taken for first panicle initiation (54.28 days) was observed in K_1-50 kg ha^{-1} followed by K_2-100kg ha^{-1}(54.44days). Number of days taken for first panicle initiation was at maximum (54.83 days) with the application of the highest dose of nitrogen N_3 -225 kg ha^{-1} and among phosphorus levels P_3-225 kg ha^{-1} recorded maximum value (54.57 days). Whereas among potassium levels K_3-150 kg ha^{-1} recorded maximum value (54.66 days).

Among the interactions, the number of days taken for first panicle initiation was at the highest (54.26 days) by the combination of $N_3P_3K_3$ (225+225+150 kg ha^{-1}) which was significantly superior to $N_1P_1K_3$ (75+75+150 kg ha^{-1}) (53.23 days) and $N_2P_1K_1$ (54.23 days).

In golden rod, the inflorescence is capitulum, but it appears like a small floret and stalked. Numerous capitula arise on the branched plageotropic portion of the main stem which gives an appearance of panicle with a few leaves arising in between. In the present study the earliest flowering was observed by the application of the lowest dose of nitrogen. There was significant delay in the higher doses *i.e.* N_2 and N_3. However, the difference between them was not significant with respect to days taken for first panicle initiation**.**

This might be due to increased vigour and enhanced vegetative growth of plants receiving 150 and 225 kg ha^{-1} of nitrogen and phosphorus as well as potassium at the rate of 100 and 150 kg ha^{-1}. These plants, as a result of maximum uptake of nutrients by individual plant, might have diverted maximum proportion of photosynthates into vegetative parts in the initial life significantly postponingtheir transition into reproductive phase. Further late occurrence in the developmental phases *viz*., complete flowering, first harvesting and panicle initiation might be prospective to the time taken for first initiation of panicles by the highly nurtured and widely spaced plants. These results are in concurrence with the findings of those reported by Jadhav *et al.*, (2014) in calendula, Naidu *et al*., (2014) in marigold, Sharma *et al*., (2012) in marigold.

Number of days taken for opening of firstfloret

It is evident from the tabulated data (Table 2) that the minimum number of days taken for first floret opening (6.99 days) was recorded by N_1-75 kg ha^{-1} level followed N_2 -150 kg ha^{-1} (7.46 days) whereas, N_3-225 kgha^{-1} recorded maximum number of days (7.48 days) for first floret opening. Among phosphorus levels P_1-75 kg ha^{-1} recorded the minimum number of days for first floret opening (7.18 days) preceded by P_2-150 kg ha^{-1} (7.36 days) on the other hand, P_3-225 kg ha^{-1} recorded maximum number of days (7.39 days).With respect to potassium levels, K_1-50 kg ha^{-1} recorded minimum number of days (7.12 days) and preceded by K_2 -75 kg ha^{-1}(7.35 days). The latest first floret opening was observed in K_3-150 kg ha^{-1} (7.46 days). Among the interactions, minimum number of days taken for first floret opening (6.44 days) was recorded by the combination of $N_1P_1K_1$ (75+75+50 kg ha^{-1}) and maximum number of days were taken for first floret opening by the application of N_3 P_3 K_3 (225+225+150 kg ha^{-1}) (7.67 days).

Table 2: Number of days taken for opening of first floret as influenced by nitrogen, phosphorus, potassium and their interaction in golden rod.

No. of days taken for opening of first floret (days)					
N levels					
P levels	**K levels**	**N_1(75)**	**N_2(150)**	**N_3(225)**	**Mean**
P_1(75)	K_1(50)	6.44	7.23	7.25	**6.97**
	K_2(100)	6.87	7.42	7.45	**7.25**
	K_3(150)	6.90	7.53	7.54	**7.32**
	Mean	**6.74**	**7.39**	**7.41**	**7.18**
P_2(150)	K_1(50)	6.89	7.32	7.35	**7.19**
	K_2(100)	7.12	7.51	7.52	**7.38**
	K_3(150)	7.23	7.64	7.65	**7.51**
	Mean	**7.08**	**7.49**	**7.51**	**7.36**
P_3(225)	K_1(50)	6.92	7.33	7.34	**7.20**
	K_2(100)	7.16	7.52	7.56	**7.41**
	K_3(150)	7.34	7.65	7.67	**7.55**
	Mean	**7.14**	**7.50**	**7.52**	**7.39**
	For comparison between N and K levels				
	K_1(50)	6.75	7.29	7.31	***7.12***
	K_2(100)	7.05	7.48	7.51	***7.35***
	K_3(150)	7.16	7.61	7.62	***7.46***
	Mean	***6.99***	***7.46***	***7.48***	***7.31***
		SEm		**CD at 5%**	
N levels		0.06		0.16	
P levels		0.06		0.16	
K levels		0.06		0.16	
N × P		0.09		0.26	
P × K		0.09		0.26	
N × K		0.09		0.26	
N × P × K		0.14		0.41	

Number of days taken for 50% flowering

It is evident from the tabulated data (Table 3) N_1-75 kg ha^{-1} level took the least number of days for 50% flowering (79.02 days) whereas, N_3-225 kg ha^{-1} recorded maximum number of days (81.72 days) for 50% flowering and was on par with N_2 (81.04 days). Among phosphorus levels P_1-75 kg ha^{-1} recorded the minimum number of days for 50% flowering (80.00 days) preceded by P_2-

Table 3: Number of days taken to 50% flowering as influenced by nitrogen, phosphorus, potassium and their interaction in golden rod.

Days taken to 50% flowering					
N levels					
P levels	K levels	N_1(75)	N_2(150)	N_3(225)	Mean
P_1(75)	K_1(50)	77.08	78.63	79.70	**78.47**
	K_2(100)	78.74	80.41	79.87	**79.67**
	K_3(150)	79.91	82.09	83.57	**81.85**
	Mean	**78.58**	**80.38**	**81.05**	**80.00**
P_2(150)	K_1(50)	77.44	79.78	80.84	**79.68**
	K_2(100)	79.33	81.74	81.20	**80.05**
	K_3(150)	81.43	83.46	85.00	**82.03**
	Mean	**78.93**	**80.93**	**81.60**	**81.89**
P_3(225)	K_1(50)	77.43	79.72	80.77	**79.90**
	K_2(100)	79.39	81.58	81.02	**79.98**
	K_3(150)	81.84	83.98	85.53	**82.22**
	Mean	**79.10**	**81.15**	**81.83**	**82.24**
	For comparison between N and K levels				
	K_1(50)	77.32	79.38	80.44	***79.04***
	K_2(100)	79.15	81.24	80.70	***80.36***
	K_3(150)	81.06	83.18	84.70	***82.98***
	Mean	***79.02***	***81.04***	***81.72***	***80.59***
		SEm		**CD at 5%**	
N levels		0.31		0.88	
P levels		0.31		0.88	
K levels		0.31		0.88	
N × P		0.48		1.37	
P × K		0.48		1.37	
N × K		0.48		1.37	
N × P × K		0.56		1.59	

Table 4: Number of days taken to complete flowering as influenced by nitrogen, phosphorus, potassium and their interaction in golden rod.

Days taken to Complete flowering					
N levels					
P levels	K levels	N_1(75)	N_2(150)	N_3(225)	Mean
P_1(75)	K_1(50)	81.08	82.42	83.70	**82.40**
	K_2(100)	82.74	84.32	83.66	**83.57**
	K_3(150)	83.87	86.09	87.23	**85.73**
	Mean	**82.56**	**84.28**	**84.86**	**83.90**
P_2(150)	K_1(50)	81.41	83.78	84.36	**83.54**
	K_2(100)	83.33	84.74	85.20	**83.80**
	K_3(150)	85.23	86.93	88.36	**85.63**
	Mean	**82.89**	**84.65**	**85.34**	**85.57**
P_3(225)	K_1(50)	81.32	82.72	84.77	**83.61**
	K_2(100)	83.52	85.58	85.36	**83.88**
	K_3(150)	85.22	87.95	87.99	**85.94**
	Mean	**83.02**	**84.86**	**85.53**	**85.76**
	For comparison between N and K levels				
	K_1(50)	81.27	82.97	84.28	***82.84***
	K_2(100)	83.20	84.88	84.74	***84.27***
	K_3(150)	84.77	86.99	87.86	***86.54***
	Mean	***82.95***	***84.77***	***85.43***	***84.39***
		SEm		**CD at 5%**	
N levels		0.16		0.46	
P levels		0.16		0.46	
K levels		0.16		0.46	
N × P		0.25		0.74	
P × K		0.25		0.74	
N × K		0.25		0.74	
N × P × K		0.40		1.17	

150 kg ha^{-1} (81.89 days). On the other hand, P_3 -225 kg ha^{-1} recorded maximum number of days (82.24 days). With respect to potassium levels, K_1 -50 kg ha^{-1} recorded minimum number of days (79.04 days) and preceded by K_2-75 kgha^{-1} (80.36 days). The maximum number of days taken for 50% flowering was observed in K_3-150 kg ha^{-1} (82.98 days).

Among the interactions, minimum number of days taken for 50% flowering (77.08 days) was recorded by the combination of $N_1P_1K_1$ (75+75+50 kg ha^{-1}) and maximum number of days were taken for50% flowering by the application of N_3 P_3 K_3 (225+225+150 kg ha^{-1}) (85.53 days).

Number of days taken for complete flowering

It is evident from the tabulated data (Table 4) that among the interactions, minimum number of days taken for complete flowering (81.08 days) was recorded by the combination of N_1 P_1 K_1 (75+75+50kg ha^{-1}) and maximum number of days were taken for complete flowering by the application of N_3 P_3 K_3 (225+225+150 kg ha^{-1}) (87.99 days).

Length of inflorescence (cm)

It is evident from the tabulated data (Table 5) that among nitrogen levels, maximum inflorescence length (39.84 cm) was registered with the highest dose of nitrogen N_3 -225 kg ha^{-1} and was on par with N_2 -150 kg ha^{-1} (39.82 cm). Among phosphorus levels, P_3 -225 kg ha^{-1} was superior (39.64 cm) to P_2 -150 kg ha^{-1} (39.48 cm) in terms of inflorescence length. Similarly K_3 -150 kg ha^{-1} was found to register maximum inflorescence length (39.69 cm), on par with K_2-100 kg ha^{-1} (39.30 cm).

The length of inflorescence was at minimum with the application of N_1-75 kg ha^{-1} (38.08 cm) P_1-75 kg ha^{-1} (38.61 cm) and K_1-50 kg ha^{-1}(38.74 cm) among the main effects of the nutrients.

Among the interactions, maximum inflorescence length (40.28 cm) was recorded by the combination of

Table 5: Length of inflorescence (cm) as influenced by nitrogen, phosphorus, potassium and their interaction in golden rod.

Length of inflorescence (cm)					
N levels					
P levels	**K levels**	**N_1(75)**	**N_2(150)**	**N_3(225)**	**Mean**
P_1(75)	K_1(50)	36.12	38.36	38.38	**37.62**
	K_2(100)	37.56	39.46	39.47	**38.83**
	K_3(150)	37.89	40.12	40.15	**39.39**
	Mean	**37.19**	**39.31**	**39.33**	**38.61**
P_2(150)	K_1(50)	37.45	39.89	39.90	**39.08**
	K_2(100)	38.45	40.01	40.03	**39.50**
	K_3(150)	39.12	40.23	40.25	**39.87**
	Mean	**38.34**	**40.04**	**40.06**	**39.48**
P_3(225)	K_1(50)	38.56	39.99	40.00	**39.52**
	K_2(100)	38.67	40.03	40.06	**39.59**
	K_3(150)	38.89	40.25	40.28	**39.81**
	Mean	**38.71**	**40.09**	**40.11**	**39.64**
	For comparison between N and K levels				
	K_1(50)	37.38	39.41	39.43	***38.74***
	K_2(100)	38.23	39.83	39.85	***39.30***
	K_3(150)	38.63	40.20	40.23	***39.69***
	Mean	***38.08***	***39.82***	***39.84***	***39.24***
		SEm		**CD at 5%**	
N levels		0.20		0.58	
P levels		0.20		0.58	
K levels		0.20		0.58	
N × P		0.32		0.93	
P × K		0.32		0.93	
N × K		0.32		0.93	
N × P × K		0.51		1.49	

Table 6: No. of primary branches per panicle as influenced by nitrogen, phosphorus, potassium and their interaction in golden rod.

No. of primary branches per panicle					
N levels					
P levels	**K levels**	**N_1(75)**	**N_2(150)**	**N_3(225)**	**Mean**
P_1(75)	K_1(50)	26.15	27.53	27.54	**27.07**
	K_2(100)	26.53	27.68	27.69	**27.30**
	K_3(150)	26.87	27.90	27.93	**27.57**
	Mean	**26.52**	**27.70**	**27.72**	**27.31**
P_2(150)	K_1(50)	26.90	27.63	27.65	**27.39**
	K_2(100)	27.35	27.76	27.77	**27.63**
	K_3(150)	27.87	27.99	28.00	**27.95**
	Mean	**27.37**	**27.79**	**27.81**	**27.66**
P_3(225)	K_1(50)	26.98	27.66	27.68	**27.44**
	K_2(100)	27.45	27.77	27.78	**27.67**
	K_3(150)	27.90	27.99	28.01	**27.97**
	Mean	**27.44**	**27.81**	**27.82**	**27.69**
	For comparison between N and K levels				
	K_1(50)	26.68	27.61	27.62	***27.30***
	K_2(100)	27.11	27.74	27.75	***27.53***
	K_3(150)	27.55	27.96	27.98	***27.83***
	Mean	***27.11***	***27.77***	***27.78***	***27.55***
		SEm		**CD at 5%**	
N levels		0.08		0.22	
P levels		0.08		0.22	
K levels		0.08		0.22	
N × P		0.12		0.36	
P × K		0.12		0.36	
N × K		0.12		0.36	
N × P × K		0.20		1.57	

$N_3P_3K_3$ (225+225+150 kg ha^{-1}) which were significantly superior to $N_1P_3K_3$ (75+225+150 kg ha^{-1}) (38.89 cm).

Number of primary branches per panicle

It is evident from the tabulated data (Table 6) that the mean number of primary branches per panicle were found to be maximum (27.78) with N_3-225 kg ha^{-1} level of nitrogen which was on par N_2-150 kg ha^{-1} (27.77). Among phosphorus levels, P_3-225 kg ha^{-1} registered maximum number of primary branches per panicle (27.69) on par with P_2-150kg ha^{-1} (27.66). Among the potassium levels K_3 -150 kg ha^{-1} recorded the highest number of primary branches per panicle (27.83) and was on par with K_2-100 kg ha^{-1} (27.53).

The minimum number of primary branches (27.11) was recorded with N_1- 75 kg ha^{-1} level of nitrogen. Among phosphorus levels minimum value (27.31) was recorded with P_1 -75 kg ha^{-1}. Regarding potassium levels, minimum value (27.30) was registered by K_1-50 kg ha^{-1}.

Among the interactions, maximum number of primary branches per panicle per plot (28.01) was recorded by the combination of $N_3P_3K_3$ (150+150+100 kgha^{-1}) which was significantly superior to $N_3P_2K_3$ (225+150+150kg ha^{-1}), (28.00).

Differential doses of nitrogen have significant effect on number of primary branches. There was significant increase in number of branches by applying higher dose of nitrogen. Nitrogen being a growth promoting nutrient helps in synthesis of protein and increases the cell division and cell enlargement which results in the increased growth of the plant. Similar result was obtained by Chadha *et al.,* (1999) in marigold. Phosphorus at increasing levels also showed increase in number of primary branches. These results are in accordance with the findings of Kumar *et al.,* (2002) in *Tagetes erecta* cv. Pusa Narangi. Nitrogenand phosphorus is most important for plant growth and also enhances the vegetative growth by Ahmad *et al.,* (2010).

The potassium nutrient, involved in the translocation of carbohydrates to the meristematic tissue, would have

Table 7: Number of panicles per plot as influenced by nitrogen, phosphorus, potassium and their interaction in golden rod.

Number of panicles per plot					
N levels					
P levels	**K levels**	**N_1(75)**	**N_2(150)**	**N_3(225)**	**Mean**
P_1(75)	K_1(50)	34.80	42.00	42.24	**39.68**
	K_2(100)	37.44	43.68	44.16	**41.76**
	K_3(150)	40.56	46.08	47.04	**44.56**
	Mean	**37.60**	**43.92**	**44.48**	**42.00**
P_2(150)	K_1(50)	40.56	44.16	44.40	**43.04**
	K_2(100)	42.72	46.08	44.16	**44.32**
	K_3(150)	44.16	47.04	47.52	**46.24**
	Mean	**42.48**	**45.76**	**45.36**	**44.53**
P_3(225)	K_1(50)	41.76	47.04	44.88	**44.56**
	K_2(100)	45.36	44.40	46.80	**45.52**
	K_3(150)	45.56	47.52	47.76	**46.95**
	Mean	**44.23**	**46.32**	**46.48**	**45.68**
	For comparison between N and K levels				
	K_1(50)	39.04	44.40	43.84	***42.43***
	K_2(100)	41.84	44.72	45.04	***43.87***
	K_3(150)	43.43	46.88	47.44	***45.92***
	Mean	***41.44***	***45.33***	***45.44***	***44.07***
		SEm		**CD at 5%**	
N levels		0.14		0.40	
P levels		0.14		0.40	
K levels		0.14		0.40	
N × P		0.22		0.65	
P × K		0.22		0.65	
N × K		0.22		0.65	
N × P × K		0.36		1.03	

increased the cell division and cell elongation thereby increased the number of primary branches per plant. These results are in conformity with the earlier findings of Kishore *et al.*, (2010) and Pal and Ghosh (2010) in African marigold, Sharma *et al.*, (2013) in *Barleria cristata*, Shah *et al.*, (2014) in *Zinnia elegance*.

Number of panicles per plot

It is evident from the tabulated data (Table 7) the nitrogen level N_3- 225 kg ha^{-1} recorded the highest number of panicles per plot (45.44) on par with N_2-150 kg ha^{-1} (45.33). Among phosphorus levels, P_3 -225 kg ha^{-1} was the best with the highest number of panicles per plot (45.68) followed by P_2-150 kg ha^{-1} (44.53). Among the potassium levels, K_3 -150 kg ha^{-1} recorded the highest number of panicles per plot (45.92), followed by K_2 -100 kg ha^{-1} (43.87). The minimum number of panicles per plot (41.44) was recorded by N_1-75 kg ha^{-1} among nitrogen levels. Among phosphorus levels, P_1-75 kg ha^{-1} registered the minimum number of panicles per plot (42.00). Among potassium levels K_1-50 kg ha^{-1} registered the least number of panicles per plot (42.43).

Among the interactions, maximum number of panicles per plot (47.76) was recorded by the combination of $N_3P_3K_3$ (150+150+100 kg ha^{-1}) which was significantly superior to N_2 P_3 K_3 (150+225+150kg ha^{-1}), N_2 P_3 K_1 (150+225+50 kg ha^{-1}), N_3 P_1 K_3 (225+75+150 kg ha^{-1}) (47.04).

The increase in phosphorus might have promoted the initiation of flower primordial formation leading to increase in number of flower and flower yield per plant in African marigold. The significant increase in the number of flowers with the application of increasing levels of phosphorus was also reported in African marigold by Sharma *et al.*, (2010).

The increase in flower yield might be attributed to increased supply of major nutrients like N and P which played their unique functions in the growth and development of plants (Ahirwar *et al.*, 2012). These results are in close conformity with those of Baboo and Singh (2003) and Gaikwad *et al.*, (2004).

Number of panicles per ha (lakhs)

Significant differences were noticed with respect to number of paniclesper ha among the different levels of nitrogen, phosphorus, potassium and their interactions (Table 8). The highest number of panicles per ha (1.91 lakhs) was registered by the highest dose of nitrogen N_3-225 kg ha^{-1} on par with N_2-150 kg ha^{-1} (1.89 lakhs) among nitrogen levels whereas, P_3 registered best value (1.90 lakhs) on par with P_2-150 kg ha^{-1} (1.87 lakhs) among phosphorus levels. Among the potassium levels K_3-150 kg ha^{-1} recorded maximum value (1.91 lakhs) and was on par with K_2-100 kg ha^{-1} (1.85 lakhs).

Among the interactions, maximum number of panicles per ha^{-1} (1.99) was recorded by the combination of N_3 P_3 K_3 (225+225+150 kg ha^{-1}) which was significantly superior to N_1 P_1 K_1 (75+75+50 kg ha^{-1}) (1.45).

Number of days taken for first harvest

The effect of levels of nitrogen, phosphorus, potassium and their interactions were found significant with respect to number of days for first harvesting (Table 9).

Among nitrogen levels, an early harvesting (96.72 days) was recorded by N_1 75 kg ha^{-1} followed by N_2 - 150 kg ha^{-1} (98.17 days). Among phosphorus levels, P_2-150 kg ha^{-1} recorded minimum number of days (97.78 days) preceded

Among the interactions, maximum number of days for first harvest (99.03 days) was recorded by the

Table 8: Number of panicles per hectare (lakhs) as influenced by nitrogen, phosphorus, potassium and their interaction in golden rod.

Number of panicles per hectare (Lakhs)					
N levels					
P levels	**K levels**	**N_1(75)**	**N_2(150)**	**N_3(225)**	**Mean**
P_1(75)	K_1(50)	1.45	1.75	1.76	**1.65**
	K_2(100)	1.56	1.82	1.84	**1.74**
	K_3(150)	1.69	1.92	1.96	**1.86**
	Mean	**1.57**	**1.83**	**1.85**	**1.75**
P_2(150)	K_1(50)	1.69	1.84	1.85	**1.79**
	K_2(100)	1.78	1.96	1.96	**1.89**
	K_3(150)	1.84	1.96	1.98	**1.93**
	Mean	**1.77**	**1.91**	**1.93**	**1.87**
P_3(225)	K_1(50)	1.74	1.85	1.87	**1.82**
	K_2(100)	1.89	1.93	1.95	**1.92**
	K_3(150)	1.90	1.98	1.99	**1.96**
	Mean	**1.84**	**1.92**	**1.94**	**1.90**
	For comparison between N and K levels				
	K_1(50)	1.63	1.81	1.83	***1.76***
	K_2(100)	1.74	1.89	1.92	***1.85***
	K_3(150)	1.81	1.95	1.98	***1.91***
	Mean	***1.73***	***1.89***	***1.91***	***1.84***
		SEm		**CD at 5%**	
N levels		0.02		0.06	
P levels		0.02		0.06	
K levels		0.02		0.06	
N × P		0.03		0.09	
P × K		0.03		0.09	
N × K		0.03		0.09	
N × P × K		0.05		0.15	

Table 9: Number of days taken for the first harvest as influenced by nitrogen, phosphorus, potassium and their interaction in golden rod.

Days taken for the first harvest					
N levels					
P levels	**K levels**	**N_1(75)**	**N_2(150)**	**N_3(225)**	**Mean**
P_1(75)	K_1(50)	96.12	97.85	98.89	**97.62**
	K_2(100)	96.48	97.98	99.01	**97.82**
	K_3(150)	96.56	98.20	99.03	**97.93**
	Mean	**96.39**	**98.01**	**98.98**	**97.79**
P_2(150)	K_1(50)	96.75	97.98	97.99	**97.57**
	K_2(100)	96.89	98.23	98.26	**97.79**
	K_3(150)	96.99	98.43	98.53	**97.98**
	Mean	**96.88**	**98.21**	**98.26**	**97.78**
P_3(225)	K_1(50)	96.74	97.99	98.00	**97.58**
	K_2(100)	96.98	98.24	98.27	**97.83**
	K_3(150)	97.00	98.63	98.68	**98.10**
	Mean	**96.91**	**98.29**	**98.32**	**97.84**
	For comparison between N and K levels				
	K_1(50)	96.54	97.94	98.29	***97.59***
	K_2(100)	96.78	98.15	98.51	***97.82***
	K_3(150)	96.85	98.42	98.75	***98.01***
	Mean	***96.72***	***98.17***	***98.52***	**97.80**
		SEm		**CD at 5%**	
N levels		0.19		0.55	
P levels		0.19		0.55	
K levels		0.19		0.55	
N × P		0.30		0.88	
P × K		0.30		0.88	
N × K		0.30		0.88	
N × P × K		0.49		1.41	

combination of $N_3P_1K_3$ (225+75+150 kgha^{-1}), whereas, significantly minimum number of days for first harvest was recorded by $N_2P_1K_1$ (150+75+50 kgha^{-1}) (97.85 days).

Based on the results obtained it could be concluded that number of days taken toharvest the flowers were found to be gradually increased with increasing levels of application of graded levels of nitrogen, phosphorus and potassium. Application of higher doses of nitrogen and potassium delayed the flowering as well as flower harvesting due to diversion of nutrients and the photo assimilates towards the vegetative growth than reproductive development. Similar findings were earlier reported by Anuradha *et al.*, (1990) in marigold, Belgoankar *et al.*, (1996) in annual chrysanthemum, Sharma *et al.*, (2013) in *Barleria cristata* and Shah *et al.*, (2014) in *Zinnia elegans*.

In situ longevity of flower panicles (days)

The data regarding the longevity of panicle in field as influenced by different levels of nitrogen, phosphorus, potassium and their interactions are presented in (Table 10). The effect of different levels of nitrogen, phosphorus, potassium and their interactions were found significant with respect to longevity of panicle in field.

Maximum longevity (20.71 days) was observed with N_3-225 kg ha^{-1} level of nitrogen and it was on par with N_2-150 kg ha^{-1} (20.68 days), on the other side N_1-75 kg ha^{-1} recorded minimum longevity (18.66 days). Among phosphorus levels, P_3-225 kg ha^{-1} recorded maximum longevity (20.15 days) and it was on par with P_2-150 kgha^{-1} (20.08 days) whereas, minimum value was observed with P_1 -75 kg ha^{-1} (19.82 days). Among potassium levels, K_3 -150 kg ha^{-1} recorded maximum longevity (20.19 days) and it was on par with K_2-100 kg ha^{-1} (20.02 days) whereas, minimum value was observed with K_1-50 kg ha^{-1} (19.84 days).

Among the interactions, maximum longevity (20.95 days) was recorded by the combination of $N_3P_3K_3$ (225+225+150 kg ha^{-1}) which was significantly superior to $N_2P_1K_1$ (150+75+50 kg ha^{-1}) (20.33 days).

Table 10: *In situ* longevity (days) of flower panicles as influenced by nitrogen, phosphorus, potassium and their interaction in golden rod.

***In Situ* logevity of flower panicles (Days)**					
N levels					
P levels	**K levels**	**N_1(75)**	**N_2(150)**	**N_3(225)**	**Mean**
P_1(75)	K_1(50)	18.10	20.33	20.34	**19.59**
	K_2(100)	18.25	20.56	20.58	**19.80**
	K_3(150)	18.68	20.74	20.77	**20.06**
	Mean	**18.34**	**20.54**	**20.56**	**19.82**
P_2(150)	K_1(50)	18.55	20.58	20.60	**19.91**
	K_2(100)	18.78	20.76	20.78	**20.11**
	K_3(150)	18.88	20.89	20.92	**20.23**
	Mean	**18.74**	**20.74**	**20.77**	**20.08**
P_3(225)	K_1(50)	18.86	20.59	20.62	**20.02**
	K_2(100)	18.89	20.79	20.81	**20.16**
	K_3(150)	18.92	20.92	20.95	**20.26**
	Mean	**18.89**	**20.77**	**20.79**	**20.15**
	For comparison between N and K levels				
	K_1(50)	18.50	20.50	20.52	***19.84***
	K_2(100)	18.64	20.70	20.72	***20.02***
	K_3(150)	18.83	20.85	20.88	***20.19***
	Mean	***18.66***	***20.68***	***20.71***	***20.02***
		SEm		**CD at 5%**	
N levels		0.24		0.68	
P levels		0.24		0.68	
K levels		0.24		0.68	
N × P		0.38		1.09	
P × K		0.38		1.09	
N × K		0.38		1.09	
N × P × K		0.60		1.74	

Table 11: Vase life (days) as influenced by of nitrogen, phosphorus, potassium and their interaction in golden rod.

Vase life (Days)					
N levels					
P levels	**K levels**	**N_1(75)**	**N_2(150)**	**N_3(225)**	**Mean**
P_1(75)	K_1(50)	6.31	7.12	7.14	**6.86**
	K_2(100)	6.59	7.16	7.18	**6.98**
	K_3(150)	6.88	7.18	7.20	**7.09**
	Mean	**6.59**	**7.15**	**7.17**	**6.97**
P_2(150)	K_1(50)	6.98	7.09	7.12	**7.06**
	K_2(100)	7.02	7.19	7.20	**7.14**
	K_3(150)	7.06	7.20	7.21	**7.16**
	Mean	**7.02**	**7.16**	**7.18**	**7.12**
P_3(225)	K_1(50)	6.99	7.08	7.12	**7.06**
	K_2(100)	7.04	7.20	7.21	**7.15**
	K_3(150)	7.08	7.23	7.25	**7.19**
	Mean	**7.04**	**7.17**	**7.19**	**7.13**
	For comparison between N and K levels				
	K_1(50)	6.76	7.10	7.13	***6.99***
	K_2(100)	6.88	7.18	7.20	***7.09***
	K_3(150)	7.01	7.20	7.22	***7.14***
	Mean	***6.88***	***7.16***	***7.18***	***7.08***
		SEm		**CD at 5%**	
N levels		0.03		0.10	
P levels		0.03		0.10	
K levels		0.03		0.10	
N × P		0.05		0.15	
P × K		0.05		0.15	
N × K		0.05		0.15	
N × P × K		0.08		0.25	

Vase life (days)

There were significant differences among the nitrogen, phosphorus, potassium and their interactions with regard to vase life of golden rod panicles (Table 11). Maximum vase life of panicle (7.18 days) was recorded in N_3-225 kg ha^{-1} on par with N_2-150 kg ha^{-1} (7.16 days) among nitrogen levels. Phosphorus level P_3 -225 kg ha^{-1} recorded maximum value (7.13 days) was on par with P_2 (7.12 days), whereas among the potassium levels, K_3-150 kg ha^{-1} recorded maximum vase life (7.14 days) and was on par with K_2-100 kg ha^{-1} (7.09 days).

The minimum vase life of panicle was registered by N_1-75 kg ha^{-1} (7.04 days) among nitrogen levels whereas among phosphorus levels, minimum values was recorded with P_1-75 kg ha^{-1} (6.97 days) and among potassium levels K_1-50 kg ha^{-1} recorded minimum vase life (6.99 days).

Among the interactions, maximum vase life (7.25 days) was recorded by the combination of $N_3P_3K_3$ (225+225+150 kg ha^{-1}) which were significantly superior to $N_1 P_2 K_2$ (75+150+100 kg ha^{-1}) (7.02 days).

The present study is also revealing that the quality parameters like number of primary branches per panicle, spread and length of inflorescence, longevity of flower and vase life was significantly higher with higher doses of nitrogen, phosphorus and potassium. However, the combinations of $N_3 P_3 K_3$ (225+225+150 Kg h^{-1} and $N_2 P_2 K_2$ (150+150+100 Kg h^{-1}) were showing on par results with respect to a majority of quality parameters *viz.*, length of inflorescence, number of primary branches, vase life and longevity. This might be due to the reason that higher doses of N P K might have resulted in increased amount of assimilates which were involved in the development of inflorescence taking relatively more time in its linear expansion. This might have eventually caused a further delay in opening of individual florets and subsequent phases, thus recording a higher *in situ* longevity and vase life, with higher doses of NPK. A high protoplasmic content of cells can be ascribed as a reason for increased longevity and vase life at high nitrogen and phosphorus as stated by Lale *et al.*, (2003) in golden rod. These results are also supported by the findings of Kurupaiah and Krishna (2005) in tuberose, and Khalaj *et al.*, (2012) in marigold.

Summary:

The effects of nitrogen (N), phosphorus (P), and potassium (K) on the growth, yield, and quality of golden rod using a 3×3 factorial design with 27 treatment combinations, each replicated twice. The study found:

- **Flowering Time**: The earliest flowering was observed with the lowest nitrogen dose (75 kg ha^{-1}), while higher doses (150 and 225 kg ha^{-1}) caused significant delays.
- **Panicles per hectare**:

1. **Nitrogen:** The highest dose (225 kg ha^{-1}) resulted in the highest number of panicles (1.94 lakhs), comparable to the 150 kg ha^{-1} dose (1.92 lakhs).
2. **Phosphorus:** The highest dose (225 kg ha^{-1}) produced the best results (1.90 lakhs), similar to the 150 kg ha^{-1} dose (1.87 lakhs).
3. **Potassium:** The highest dose (150 kg ha^{-1}) recorded the maximum number (1.91 lakhs), comparable to the 100 kg ha^{-1} dose (1.85 lakhs).

- **Interactions**: The combination N_3 P_3 K_3 (225+225+150 kg ha^{-1}) resulted in the maximum panicles per hectare (1.99 lakhs), significantly superior to the lowest combination $N_1P_1K_1$ (75+75+50 kg ha^{-1}) (1.45 lakhs).
- **Quality Parameters**: The combinations N_3 P_3 K_3 (225+225+150 kg ha^-1) and N_2 P_2 K_2 (150+150+100 kg ha^{-1}) were on par concerning inflorescence length, number of primary branches, vase life, and longevity.
- **Economic Analysis**: The highest benefit-cost ratio (3.13) was observed with the combination N_2 P_1 K_3 (150+75+150 kg ha^{-1}).

Conclusion

Optimal Nutrient Application

For optimal vegetative and reproductive growth of golden rod, the application of NPK at 225+225+150 kg ha^{-1} is recommended. This combination yields the best results in terms of growth and flower quality.

Cost-Effectiveness

The combination N^2 P^1 K^3 (150+75+150 kg ha^{-1}) provides the highest economic benefit, indicating a balance between high yield and cost efficiency.

General Recommendation

Both the highest (225+225+150 kg ha^{-1}) and the moderate (150+150+100 kg ha^{-1}) N P K combinations are effective, with the former being slightly superior in most parameters. The study supports the strategic use of these nutrient levels for enhanced production and economic returns in golden rod cultivation.

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