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Different NPK levels and their impacts on flowering and yield in gomphrena (*Gomphrena globosa* L.) and soil nutrient status

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Abstract
The investigation took place at the Floriculture Farm, Jambuvadi, Department of Horticulture, Junagadh Agricultural University, Junagadh (Gujarat). A Randomized Block Design with a factorial concept was employed, involving twelve treatment combinations. These combinations consisted of three levels of nitrogen (100, 150, and 200 kg ha^{-1}), two levels of phosphorus (50 and 75 kg ha^{-1}), and two levels of potassium (75 and 100 kg ha^{-1}). Regarding flowering parameters, it was found that nitrogen at 150 kg ha^{-1}, phosphorus at 75 kg ha^{-1}, and potassium at 100 kg ha^{-1} resulted in the minimum number of days required for the initiation of the first flower bud (28.21 days, 29.01 days, 28.91 days respectively), the formation of the first flower (30.79 days, 31.67 days, 31.56 days respectively), and the overall duration of flowering (75.99 days, 73.28 days, 74.02 days respectively). On the other hand, the treatment with 200 kg ha^{-1} of nitrogen, 75 kg ha^{-1} of phosphorus, and 100 kg ha^{-1} of potassium improved yield parameters, including the number of flowers per plant (117.52, 114.92, 116.88 respectively), fresh weight of 100 flowers (98.49 g, 92.51 g, 93.13 g respectively), dry weight of 100 flowers (27.99 g, 27.15 g, 27.57 g respectively), flower yield per plant (113.86 g, 105.49 g, 105.24 g respectively), and flower yield per plot (1024.73 g, 949.45 g, 947.13 g respectively). Furthermore, the soil nutrient status exhibited improvement as the availability of nitrogen, phosphorus, and potassium in the soil increased (234.92 kg ha^{-1}, 57.14 kg ha^{-1}, 230.11 kg ha^{-1} respectively).

Keywords: NPK levels, flowering, yield, *Gomphrena globosa* L.

Introduction
Gomphrena, a versatile plant native to North America, South America, Myanmar, and India, is a member of the Amaranthaceae family and is highly valued for its captivating flower heads. With its erect, branched stems, oblong-ovate leaves, and a height ranging from 1 to 2 feet, it thrives as an annual in warm temperate to tropical climates. Gomphrena's adaptability makes it an excellent choice for dry flower arrangements, indoor decorations, pomanders, garlands, bouquets, and vase displays. Notably, the flowers of Gomphrena contain betacyanin, including gomphrenin and isogomphrenin, which are striking red-violet betalain pigments (Roriz *et al.*, 2017) [14]. Moreover, various parts of the Gomphrena plant are utilized in traditional medicine for treating a wide range of ailments such as body sores, malaria, bacterial infections, jaundice, urinary problems, high cholesterol, cough, fever, diarrhoea, liver disorders, kidney disorders, and as a cooling agent (Anaswara *et al.*, 2022) [2]. Proper application of nitrogen (N), phosphorus (P), and potassium (K) fertilizers is crucial for the optimal growth and flowering of gomphrena.

Nitrogen (N) is a vital nutrient that significantly impacts plant growth and yield. It plays a crucial role in plant development by serving as a critical constituent of chlorophyll, which facilitates the process of photosynthesis and enables the conversion of water and carbon dioxide into sugars. Additionally, nitrogen promotes the growth of vibrant and abundant foliage, stimulating vegetative growth in leaves and stems. Furthermore, it enhances the uptake of other important nutrients such as potassium and phosphorus, thus contributing to the overall nutritional status of the plant. Ultimately, nitrogen acts as a regulator, effectively governing the overall growth and development of plants (Leghari *et al.*, 2016) [9].

Phosphorus (P) holds significant importance as a crucial nutrient for the growth of gomphrena. It serves as a vital component of various structural compounds within plants and acts as a catalyst in essential biochemical reactions. The addition of phosphorus to crops has been observed to have several beneficial effects, including the stimulation of root development, fortification of stalks and stems, enhancement of flower formation and seed production, facilitation of earlier and more uniform flower maturation, and improvement of flower quality (Razaq *et al.*, 2017) [13].

Potassium (K) plays a critical role as an essential activator for a multitude of vital enzymes involved in various plant processes. It is indispensable for crucial functions such as protein synthesis, sugar transport, nitrogen and carbon metabolism, as well as photosynthesis. The presence of potassium significantly impacts both yield formation and quality improvement in plants. By activating ATPase in the plasma membrane, potassium initiates acid stimulation, cell wall loosening, and hydrolase activation, thereby promoting cell growth and overall plant development (Hepler *et al.*, 2001) [6].

Materials and Methods

The present experiment was carried out in 2022 at the Floriculture Farm, Jambuvadi, Department of Horticulture, Junagadh Agricultural University, Junagadh (Gujarat). The study focused on twelve different treatment combinations, consisting of varying levels of nitrogen (N_1 = 100 kg ha^{-1}, N_2 = 150 kg ha^{-1}, and N_3 = 200 kg ha^{-1}), two levels of phosphorus (P_1 = 50 kg ha^{-1} and P_2 = 75 kg ha^{-1}), and two levels of potassium (K_1 = 75 kg ha^{-1} and K_2 = 100 kg ha^{-1}). The nutrients were applied in the form of urea, single super phosphate (SSP), and muriate of potash (MOP), respectively. Urea was applied in two split doses along with the full doses of SSP and MOP. The remaining half dose of urea was applied one month later. The experiment was conducted using a Factorial Randomised Block Design (FRBD) with three replications. Gomphrena seedlings, which were forty days old and in good health, were transplanted with a spacing of 30 x 20 cm.

Physio-Chemical properties of soil (before NPK application)

EC (dS m^{-1})	pH	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
0.42	7.6	210.12	28.21	201.83

Results and Discussion

Flowering parameters

Effect of nitrogen

Significantly minimum number of days to first flower bud initiation and first flower formation (28.21 days and 30.79 days respectively) were taken in treatment N_2 (150 kg ha^{-1}) and maximum number of days (32.24 days and 34.14 days respectively) were seen in treatment N_3 (200 kg ha^{-1}). The reason might be that nitrogen helps in accumulation of certain energy reserves like proteins and carbohydrates, which are essential for flower bud initiation and flower formation. These results were in close conformity to that of Fayaz *et al.* (2016) [5] in gerbera, Singh *et al.* (2015) [16] in carnation, Ozukum *et al.* (2022) [11] in jasmine and Agrawal *et al.* (2016) [1] in golden rod.

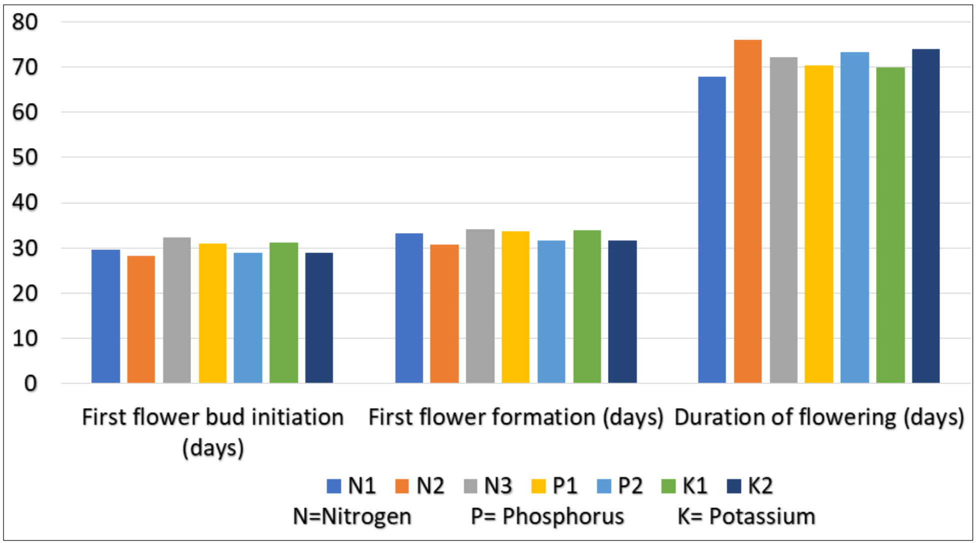
Significantly maximum duration of flowering (75.99 days) was found in treatment N_2 (150 kg ha^{-1}) and minimum duration (67.81 days) was found in treatment N_3 (200 kg ha^{-1}). Maximum duration of flowering might be due to the reason that nitrogen helps in accumulation of energy reserves in plant tissues, which are useful during the entire flowering period. These findings were similar to that of Ozukum *et al.* (2022) [11] in jasmine and Singh *et al.* (2015) [16] in carnation.

Table 1: Effect of different levels of NPK on flowering parameters

Treatment	First flower bud initiation (days)	First flower formation (days)	Duration of flowering (days)
Nitrogen (N)			
N_1 = 100 kg ha^{-1}	29.53	33.25	67.81
N_2 = 150 kg ha^{-1}	28.21	30.79	75.99
N_3 = 200 kg ha^{-1}	32.24	34.14	72.24
S.Em ±	0.771	0.777	1.294
C. D. @ 5%	2.26	2.28	3.79
Phosphorus (P)			
P_1 = 50 kg ha^{-1}	31.03	33.78	70.30
P_2 = 75 kg ha^{-1}	29.01	31.67	73.28
S.Em ±	0.630	0.634	1.056
C. D. @ 5%	1.84	1.86	3.09
Potassium (K)			
K_1 = 75 kg ha^{-1}	31.12	33.90	70.00
K_2 = 100 kg ha^{-1}	28.91	31.56	74.02
S.Em ±	0.630	0.634	1.056
C. D. @ 5%	1.84	1.86	3.09
N x P			
S.Em ±	1.091	1.099	1.830
C. D. @ 5%	NS	NS	NS
N x K			
S.Em ±	1.091	1.099	1.830
C. D. @ 5%	NS	NS	NS
P x K			
S.Em ±	0.891	0.897	1.494
C. D. @ 5%	NS	NS	NS
N x P x K			
S.Em ±	1.543	1.555	2.587
C. D. @ 5%	NS	NS	7.58
C.V. %	8.90	8.23	6.22

Table 2: Interaction effect of NPK on duration of flowering

Treatment combination (kg ha^{-1})	Duration of flowering (days)
100: 50: 75	59.03
100: 50: 100	71.56
100: 75: 75	68.75
100: 75: 100	71.90
150: 50: 75	79.48
150: 50: 100	71.47
150: 75: 75	71.10
150: 75: 100	81.92
200: 50: 75	66.94
200: 50: 100	73.32
200: 75: 75	74.75
200: 75: 100	73.96
S. Em ±	2.587
C. D. @ 5%	7.58
C. V. %	6.22



Graph 1: Effect of different levels of NPK on flowering parameters

Effect of phosphorus

Significantly minimum number of days to first flower bud initiation and first flower formation (29.01 days and 31.67 days respectively) were taken in treatment P_2 (75 kg ha^{-1}) and maximum number of days (31.03 days and 33.78 days respectively) were seen in treatment P_1 (50 kg ha^{-1}). The reason associated with this might be that phosphorus is involved in the synthesis of ATP, which is necessary for many cellular processes like flower bud initiation and flower formation. These results were in close conformity to that of Fayaz *et al.* (2016) [5] in gerbera and Singh *et al.* (2015) [16] in carnation and Parasana *et al.* (2023) [12] in custard apple.

Significantly maximum duration of flowering (73.28 days) was found in treatment P_2 (75 kg ha^{-1}) and minimum duration (70.30 days) was found in treatment P_1 (50 kg ha^{-1}). The reason for longer flowering duration might be that plants require energy during its flowering period in the form of ATP, whose significant component is phosphorus. These findings were similar to that of Singh *et al.* (2015) [16] in carnation.

Effect of potassium

Significantly minimum number of days to first flower bud initiation and first flower formation (28.91 days and 31.56 days respectively) were taken in treatment K_2 (100 kg ha^{-1}) and maximum number of days (31.12 days and 33.90 days respectively) were seen in treatment K_1 (75 kg ha^{-1}). The reason associated with this might be that potassium helps in the formation and transport of carbohydrates, which are required for flower bud initiation and flower formation. It also helps in the activation of enzymes involved in energy metabolism, needed during flowering period. These results were in close conformity to that of Fayaz *et al.* (2016) [5] in gerbera and Singh *et al.* (2015) [16] in carnation.

Significantly maximum duration of flowering (74.02 days) was found in treatment K_2 (100 kg ha^{-1}) and minimum duration (70.00 days) was found in treatment K_1 (75 kg ha^{-1}). Potassium helps in the formation and transport of carbohydrates, and also helps in the activation of enzymes involved in energy metabolism, needed during flowering period. This might be the reason for increased flowering duration. These findings were similar to that of Singh *et al.* (2015) [16] in carnation and Kumar *et al.* (2006) [8] in gladiolus.

Interaction effect of N, P and K

Significantly maximum duration of flowering (81.92 days) was observed in treatment combination $N_2P_2K_2$ (150: 75: 100 kg ha^{-1}). Likewise, minimum duration of flowering (59.03 days) was seen in treatment combination $N_1P_1K_1$ (100: 50: 75 kg ha^{-1}). The interaction effect of nitrogen, phosphorus and potassium was found to be significant because in terms of flowering, these nutrients play an important role.

Yield parameters

Effect of nitrogen

Significantly maximum number of flowers (117.52) was observed in treatment N_3 (200 kg ha^{-1}) and minimum (107.35) was observed in treatment N_1 (100 kg ha^{-1}). This might be due to the reason that nitrogen promotes the formation of amino acids and other compounds that are involved in flower formation. These results were in close similarity to that of Kejkar and Polara (2014) [7] in spider lily and Sahu *et al.* (2021) [15] in chrysanthemum.

Fresh weight and dry weight of 100 flowers was significantly maximum (98.49 g and 27.99 g respectively) in treatment N_3 (200 kg ha^{-1}) and minimum (83.02 g and 24.10 g respectively) in treatment in N_1 (100 kg ha^{-1}). The increase in fresh weight and dry weight of 100 flowers might be due to the reason that nitrogen helps in accumulation of energy reserves during flowering period, which also result in increase in flower size, thereby increasing the flower weight. These results were in close similarity to that of Malani (2021) [10] in gomphrena and Aremsungla and Topno (2022) [3] in zinnia.

Significantly maximum flower yield per plant and per plot (113.86 g and 1024.73 g respectively) was observed in treatment N_3 (200 kg ha^{-1}) and minimum flower yield per plant and per plot (85.54 g and 769.89 g respectively) was observed in treatment N_1 (100 kg ha^{-1}) The reason attributed to this might be that nitrogen increases the formation of branches, which produces a greater number of lateral buds, thereby increasing flower formation and flower yield. These results were in close similarity to that of Malani (2021) [10] in gomphrena, Singh *et al.* (2017) [17] in China aster, Aremsungla and Topno (2022) [3] in zinnia and Vasava *et al.* (2023) [18] in brinjal.

Effect of phosphorus

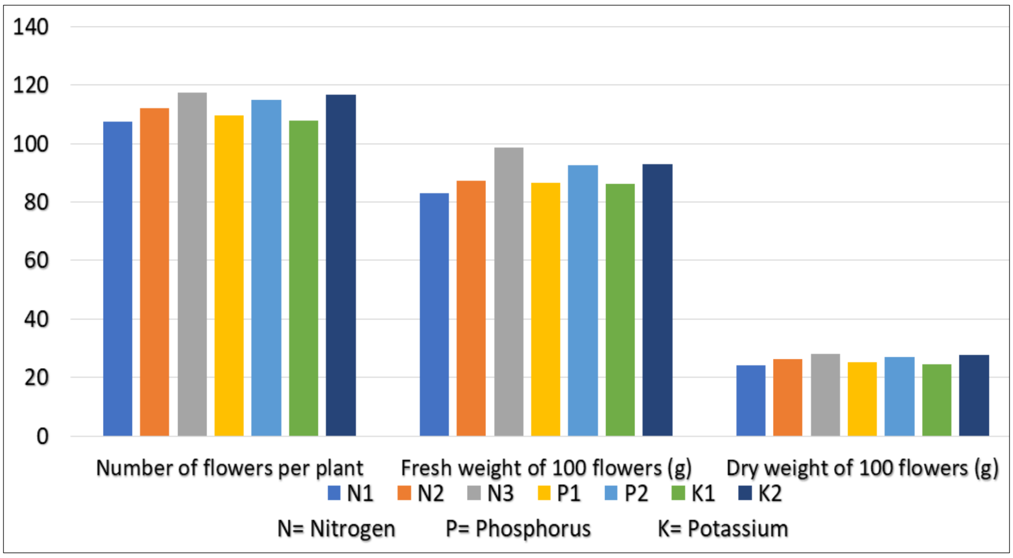
Significantly a greater number of flowers per plant (114.92) were observed in treatment P_2 (75 kg ha^{-1}) and least (109.73) in treatment P_1 (50 kg ha^{-1}). Phosphorus enhances better vegetative growth responsible for more accumulation of food and dry matter which might be the reason for increase in number of flowers per plant. These results were in close similarity to that of Sahu *et al.* (2021) [15] in chrysanthemum.

Among the two different phosphorus levels, fresh weight and dry weight of 100 flowers was significantly maximum (92.51 g and 27.15 g respectively) in treatment P_2 (75 kg ha^{-1}). Meanwhile minimum fresh weight of 100 flowers (86.75 g and 25.09 g) was found in treatment P_1 (50 kg ha^{-1}). These results were in close similarity to that of Sahu *et al.* (2021) [15] in chrysanthemum and Singh *et al.* (2017) [17] in China aster.

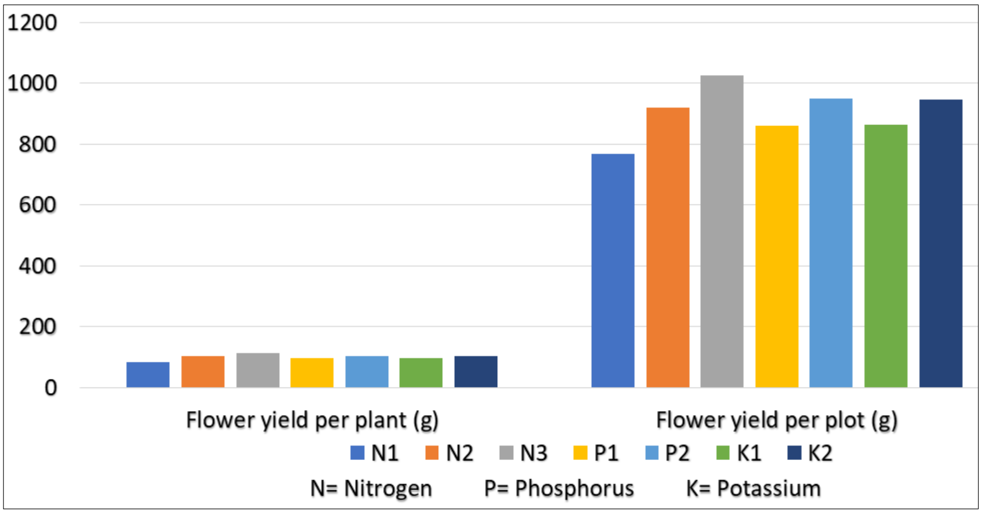
Significantly maximum flower yield per plant and per plot (105.49 g and 949.45 g) was observed in treatment P_2 (75 kg ha^{-1}). Meanwhile minimum flower yield per plant and per plot

Table 3: Effect of different levels of NPK on yield parameters

Treatment	Number of flowers per plant	Fresh weight of 100 flowers (g)	Dry weight of 100 flowers (g)	Flower yield per plant (g)	Flower yield per plot (g)
Nitrogen (N)					
N_1 = 100 kg ha^{-1}	107.35	83.02	24.10	85.54	769.89
N_2 = 150 kg ha^{-1}	112.10	87.37	26.27	102.46	922.12
N_3 = 200 kg ha^{-1}	117.52	98.49	27.99	113.86	1024.73
S.Em ±	2.014	1.684	0.705	2.764	24.881
C. D. @ 5%	5.91	4.94	2.07	8.11	72.98
Phosphorus (P)					
P_1 = 50 kg ha^{-1}	109.73	86.75	25.09	95.75	861.71
P_2 = 75 kg ha^{-1}	114.92	92.51	27.15	105.49	949.45
S.Em ±	1.644	1.375	0.576	2.257	20.315
C. D. @ 5%	4.82	4.03	1.69	6.62	59.59
Potassium (K)					
K_1 = 75 kg ha^{-1}	107.77	86.12	24.66	96.00	864.03
K_2 = 100 kg ha^{-1}	116.88	93.13	27.57	105.24	947.13
S.Em ±	1.644	1.375	0.576	2.257	20.315
C. D. @ 5%	4.82	4.03	1.69	6.62	59.59
N x P					
S.Em ±	2.848	2.382	0.998	3.910	35.186
C. D. @ 5%	NS	NS	NS	NS	NS
N x K					
S.Em ±	2.848	2.382	0.998	3.910	35.186
C. D. @ 5%	NS	NS	NS	NS	NS
P x K					
S.Em ±	2.325	1.945	0.815	3.192	28.730
C. D. @ 5%	NS	NS	NS	NS	NS
N x P x K					
S.Em ±	4.027	3.369	1.411	5.529	49.761
C. D. @ 5%	11.81	NS	NS	16.22	149.95
C.V. %	6.21	6.51	9.36	9.52	9.52



Graph 2 a): Effect of different levels of NPK on yield parameters



Graph 2 b): Effect of different levels of NPK on yield parameters

Table 4: Interaction effect of different levels of NPK on yield parameters

Treatment combination (kg ha^{-1})	Number of flowers per plant	Flower yield per plant (g)	Flower yield per plot (g)
100: 50: 75	100.20	75.32	677.91
100: 50: 100	107.08	76.88	691.91
100: 75: 75	103.02	83.40	750.64
100: 75: 100	119.09	106.57	959.11
150: 50: 75	98.25	92.74	834.62
150: 50: 100	121.89	110.39	993.48
150: 75: 75	115.80	105.53	949.74
150: 75: 100	112.48	101.18	910.63
200: 50: 75	114.78	104.25	938.23
200: 50: 100	116.14	114.90	1034.12
200: 75: 75	114.55	114.79	1033.07
200: 75: 100	124.60	121.50	1093.50
S. Em $\pm$	4.027	5.529	49.761
C. D. @ 5%	11.81	16.22	149.95
C. V. %	6.21	9.52	9.52

(95.75 g and 861.71 g respectively) was found in treatment P_1 (50 kg ha^{-1}). Phosphorus enhances better vegetative growth responsible for more accumulation of food and dry matter which might be the reason for increase in number of flowers per plant thereby increasing flower yield. These results were in close similarity to that of Singh *et al.* (2017) [17] in China aster and Aremsungla and Topno (2022) [3] in zinnia.

Effect of potassium

Significantly greater number of flowers per plant (116.88) was observed in treatment K_2 (100 kg ha^{-1}). Meanwhile, lower number of flowers per plant (107.77) was found in treatment K_1 (75 kg ha^{-1}). This might be due to the reason that potassium promotes flower bud development, thereby increasing the number of flowers overall in plant. These results were in close similarity to that of Sahu *et al.* (2021) [15] in chrysanthemum and Singh *et al.* (2017) [17] in China aster.

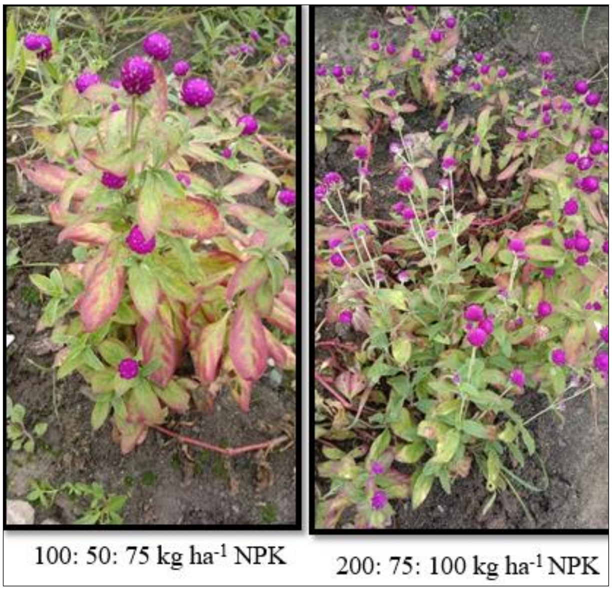
Among the two different potassium levels, fresh weight and dry weight of 100 flowers was significantly maximum (93.13 g and 27.57 g respectively) in treatment K_2 (100 kg ha^{-1}). Meanwhile minimum fresh weight and dry weight of 100 flowers (86.12 g and 24.66 g) was found in treatment K_1 (75 kg ha^{-1}). Potassium is an important element which regulates water uptake and retention, as a result of which there will be more growth in plant, including size of flowers. This increased flower size might be the reason for improved fresh weight of flowers. These results were in close similarity to that of Sahu *et al.* (2021) [15] in chrysanthemum and Singh *et al.* (2017) [17] in China aster.

Significantly maximum flower yield per plant and per plot (105.24 g and 947.13 g respectively) was observed in treatment K_2 (100 kg ha^{-1}). Meanwhile minimum flower yield per plant and per plot (96.00 g and 864.03 g respectively) was found in treatment K_1 (75 kg ha^{-1}). These results were in close similarity to that of Sahu *et al.* (2021) [15] in chrysanthemum and Singh *et al.* (2017) [17] in China aster.

Interaction effect of N, P and K

The number of flowers were significantly maximum (124.60) in treatment combination $N_3P_2K_2$ (200: 75: 100 kg ha^{-1}). The interaction effect of nitrogen, phosphorus and potassium was found to be significant because in terms number of flowers, these nutrients play an important role. These results were in close similarity to that of Sahu *et al.* (2021) [15] in chrysanthemum and Singh *et al.* (2017) [17] in China aster.

Significantly maximum flower yield per plant and per plot (121.50 g and 1093.50 g respectively) was found in treatment combination $N_3P_2K_2$ (200: 75: 100 kg ha^{-1}). This might be due to the nitrogen, phosphorus and potassium at the above rate contributed more towards yield parameters, hence flower yield was found maximum. These results were in close similarity to that of Sahu *et al.* (2021) [15] in chrysanthemum and Singh *et al.* (2017) [17] in China aster.



Difference in number of flowers per plant with application of maximum level of NPK

Soil nutrient status

(a) Available nitrogen

Effect of nitrogen

Effect of nitrogen on soil available nitrogen was found to be significant. Significantly more available nitrogen in soil (234.92 kg ha^{-1}) was observed in treatment N_3 (200 kg ha^{-1}) and minimum (215.06 kg ha^{-1}) was found in treatment N_1 (100 kg ha^{-1}). The increase in soil nitrogen level may be attributed to more level of urea application. This finding was found to be in agreement with Divyashree *et al.* (2021) [4] in gaillardia.

(b) Available phosphorus

Effect of phosphorus

Effect of phosphorus on soil available phosphorus was found to be significant. Significantly more available phosphorus in soil (57.14 kg ha^{-1}) was observed in treatment P_2 (75 kg ha^{-1}). Whereas, minimum soil available phosphorus (54.69 kg ha^{-1}) was observed in treatment P_1 (50 kg ha^{-1}). This increase in phosphorus content may be because of the higher level of phosphatic fertilizer application. This finding was found to be in agreement with Divyashree *et al.* (2021) [4] in gaillardia.

(c) Available potassium

Effect of potassium

Effect of potassium on soil available potassium was found to be significant. Significantly maximum available potassium in soil (230.11 kg ha^{-1}) was observed in treatment K_2 (100 kg ha^{-1}) and minimum (211.32 kg ha^{-1}) was observed in treatment K_1 (75 kg ha^{-1}). Due to higher level of MOP application, there might have been an increase in soil potassium. This finding was found to be in agreement with Divyashree *et al.* (2021) [4] in gaillardia.

Conclusion

Based on the findings and results presented, it can be concluded that the application of 150 kg ha^{-1}, 75 kg ha^{-1} and 100 kg ha^{-1} NPK respectively had significantly improved various flowering parameters, including the initiation of the first flower bud, the formation of the first flower, and the overall duration of flowering. However, for enhanced yield parameters and improved soil nutrient status, 200 kg ha^{-1}, 75 kg ha^{-1} and 100 kg ha^{-1} NPK respectively proved to be more beneficial. As a result, it is recommended to apply the NPK ratio of 200:75:100 kg ha^{-1} respectively for achieving improved yield in gomphrena cultivation.

Table 5: Effect of different levels of NPK on soil available nutrients

Treatment	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
Nitrogen (N)			
N_1 = 100 kg ha^{-1}	215.06	54.59	216.30
N_2 = 150 kg ha^{-1}	223.35	56.37	220.99
N_3 = 200 kg ha^{-1}	234.92	56.78	224.71
S.Em ±	5.37	1.026	6.228
C. D. @ 5%	15.75	NS	NS
Phosphorus (P)			
P_1 = 50 kg ha^{-1}	223.77	54.69	217.70
P_2 = 75 kg ha^{-1}	225.12	57.14	223.64
S.Em ±	4.385	0.838	5.085
C. D. @ 5%	NS	2.45	NS
Potassium (K)			
K_1 = 75 kg ha^{-1}	223.92	55.32	211.32
K_2 = 100 kg ha^{-1}	224.97	56.51	230.11
S.Em ±	4.385	0.838	5.085
C. D. @ 5%	NS	NS	14.91
N x P			
S.Em ±	7.595	1.451	8.807
C. D. @ 5%	NS	NS	NS
N x K			
S.Em ±	7.595	1.451	8.807
C. D. @ 5%	NS	NS	NS
P x K			
S.Em ±	6.201	1.185	7.191
C. D. @ 5%	NS	NS	NS
N x P x K			
S.Em ±	10.741	2.052	12.455
C. D. @ 5%	NS	NS	NS
C.V. %	8.28	6.35	9.77

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