EFFECT OF POTASSIUM DOSES AND MOISTURE REGIMES ON GROWTH AND YIELD OF AFRICAN MARIGOLD IN LAMJUNG, NEPAL

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ABSTRACT

Marigold is a popular ornamental plant widely grown in Nepal. However, the optimal potassium (K) dose and moisture level for maximizing its growth and yield under the agro-climatic conditions of Lamjung have not been clearly established. To identify their effect on marigold plants, the experiment was conducted at the horticultural farm of Institute of Agriculture and Animal Science, Lamjung Campus, from July to November 2023. The study was laid out under a two-factor factorial Randomized Complete Block Design (RCBD) with four K levels (40, 80, 120, and 160 kg/ha) and two moisture levels (60% and 100% of fieldcapacity (FC)), comprising eight treatments replicated three times. Other essential nutrients were applied uniformly across all treatments. Application of 120 kg/ha K significantly increased ($p \leq 0.05$) plant height, number of primary and secondary branches, canopy spread, earlier flower initiation, days to 50% flowering, number of flower heads per plant, flower diameter, flower weight per plant and flower yield. All parameters showed significantly higher values at 100% of FC. The interaction of 120 kg/ha K with 100% of FC significantly improved most attributes. The study suggests that applying 120 kg/ha K, with 100% of FC, favors the growth and yield of marigold

1. INTRODUCTION

Marigold (*Tagetes spp*.), commonly known as 'Sayapatri' in Nepali, is a popular and vibrant ornamental and medicinal plant widely cultivated in Nepal and worldwide. It is an annual, erect, hermaphrodite herbaceous plant with green stems and compound leaves (Zahara et al., 2024). It is popular in Nepal due to its large-sized flowers used for garland-making during Hindu religious ceremonies, rituals, and festivals celebrated in Nepal, like Dashain and Tihar, easy culture, and wider adaptability. It has additional applications in traditional medicine and as a natural pest repellent in agriculture (Bakshi & Ghosh, 2022). Among the essential nutrients, potassium (K) is referred to as the third major macronutrient, playing essential roles in photosynthesis, osmoregulation, stomatal movement, enzyme activation, protein synthesis, energy transfer, phloem transport, cation-anion balance, and stress resistance (Hasanuzzaman et al., 2018). Similarly, water is a primary component of plant physiology and soil water supports plant growth by providing moisture supply and transporting essential nutrients. Irrigation benefits croplands by cooling the soil and atmosphere to create a more favorable environment for plant growth (FAO, 2014). The pairing of appropriate K doses with moisture levels may create a synergistic effect, amplifying their benefits to foster the growth and yield of African marigold.

The agriculture sector engages around 66% of the total population in Nepal (FAO, 2024). Out of the total GDP of the country, agriculture contributes 24.12% (MoALD, 2023). With this, floriculture contributes only 0.0558% of total agricultural GDP, which is too low even after having the suitable agro-climatic conditions required for flower cultivation. Marigold flowers are cultivated commercially in around 157 hectares of land in 32 districts across the country (Himalayan News Service, 2020). However, most Nepalese farmers follow the chemical fertilizer recommendation of 200:80:80 kg/ha NPK (Floriculture Association Nepal, 2018) for marigold plants, which may not be optimum for all soils, climates, and varieties. Potassium deficiency exhibits stunted growth and yellowing in their leaf margins, showing phenomena like poor root systems, lodging, and yield reductions of crops (Khalil et al., 2022). A lack of K fertilizer increases plant susceptibility to various diseases and pest infestation and makes plants vulnerable to damage under various stress conditions (Hasanuzzaman et al., 2018). On the other hand, drought stress in plants may result in leaf rolling, stunning plants, leaf yellowing, scorching and permanent wilting (Kumar et al., 2023). If excessive moisture conditions persist for long time, they can lead anaerobic respiration and may produce toxic effects on plants and also affects the photosynthesis of plants (Chen et al., 2022). A field trial was required to determine the amount of potassium and moisture regimes required for any given climate in the study area. Therefore, this research trial aimed to study the influence of different potassium and moisture regimes on the growth and yield of African marigold, and to determine the optimal K and moisture levels to achieve the maximum production.

2. MATERIALS AND METHODS

2.1. Experimental site

The study was conducted in the horticultural farm of the Institute of Agriculture and Animal Science, Lamjung Campus, Sundarbazar-07, Lamjung, Nepal, from late July 2023 to mid-November 2023. This location is situated at 28°7’31” north latitude and 84°25’4” east longitude with an elevation of 991 meters above sea level. Lamjung district has diverse climatic and soil conditions. The annual average temperature is recorded from a minimum of 14.1 °C to a maximum of 26.7 °C and the annual precipitation is recorded as 2944.23 mm. Relative humidity ranges from 50% in May to 100% in December and January. According to the test and analysis of the homogenous soil sample of our experimental plot was done in the Soil and Fertilizer Testing Laboratory, Gandaki province, Nepal. The initial soil pH was 6 (slightly acidic), soil organic matter was 2.80% (medium), nitrogen content was 0.14% (medium), phosphorus content (P_2O_5) was 124.67 kg/ha (very high) and potassium content (K_2O) was 250.48 kg/ha (medium). The average level of coarse fragment intensity in our experimental area was about 18.70%.

2.2. Experimental design

The experiment was conducted in two-factor factorial Randomized Complete Block Design (RCBD) with four doses of Potassium i.e., K1 (40 kg/ha), K2 (80 kg/ha), K3 (120 kg/ha), K4 (160 kg/ha) and two moisture regimes i.e. W0 (60% of FC) and W1 (100% of FC) comprising a total of eight treatments (Table 1). Each of the eight treatments was replicated three times, creating 24 individual plots, with a dimension of 1.6 m x 0.9 m for each individual plot. Spacing between each plot and the distance between the replications was 0.5 m.

Table 1: Details of treatment combination

Treatments	Potassium Doses	Moisture Regimes
K1W1 (T1)	40 kg/ha	100% of FC
K2W1 (T2)	80 kg/ha (RDF)	100% of FC
K3W1 (T3)	120 kg/ha	100% of FC
K4W1 (T4)	160 kg/ha	100% of FC
K1W0 (T5)	40 kg/ha	60% of FC
K2W0 (T6)	80 kg/ha (RDF)	60% of FC
K3W0 (T7)	120 kg/ha	60% of FC
K4W0 (T8)	160 kg/ha	60% of FC

Note: RDF = Recommended dose of fertilizer

2.3. Cultivation practices

Seeds to be planted were collected by importing from Karma Groups of Companies, Kathmandu, Nepal. The germination percentage of seed was 85% and a purity of 99%. Seeds were carefully selected and sown at a depth of 0.5 cm in a 1:1 mixture of cocopeat and vermicompost. After 25 days, the seedlings were ready for transplanting. The experimental field was ploughed and leveled manually a week before transplanting. The field plots were prepared using measuring tapes, pegs and ropes. Well-decomposed farmyard manure (FYM) at 20 t/ha (i.e., 5.1 kg/plot) was integrated into the soil during initial land preparation. Since the experiment was conducted in RCBD, the treatments for each plot were selected randomly through the lottery method. Fertilizers and water were applied after calculation. According to the Floriculture Association Nepal (2018), the fertilizer recommendation for marigold plant is 200:80:80 kg/ha NPK. Half dose of recommended nitrogen and full dose of phosphorus and potassium were applied as a basal application. The remaining half dose of the nitrogen was split into two doses (¼ dose at 30 DAP and ¼ dose at 50 DAP). 25 g of DAP and 43g of Urea were applied per plot as a basal dose. 9.6 g /plot, 19.2 g/plot, 28.8 g/plot and 38.4 g/ plot MOP were applied as 40 kg/ha K, 80 kg/ha K, 120 kg/ha K and 160 kg/ha K respectively. The K treatments were selected to encompass levels below, near, and above the recommended dose in order to evaluate the crop response across a wide range of potassium supply. For moisture regimes, FC was calculated from the gravimetric method. 16.29 L/plot and 27.15 L/ plot water as 60% of FC and 100% of FC were irrigated at intervals of 10 days. Twenty-five days old seedlings were transplanted in the raised bed of the experimental plot. Twelve plants were planted per plot with four rows and three columns, maintaining row-to-row and plant-to-plant spacing of 40cm×30cm. Light irrigation was applied right after transplantation. All intercultural operations, such as staking, weeding, hoeing and plant protection materials were consistently performed when required. Irrigation was administered accordingly. Flowers were manually harvested when fully opened. Flowers from five randomly selected plants were harvested separately to collect experimental data.

2.4. Data collection

The observations on different parameters such as plant height, stem diameter, number of primary and secondary branches, plant canopy spread, days to flower initiation, diameter of flower, flower fresh weight, flower numbers and flower yield per hectare were recorded. Data were collected randomly from five plants per plot. Data required for plant height, stem diameter, number of primary and secondary branches, and plant canopy spread were recorded at 25, 40, and 55 days after transplanting (DAT), whereas the remaining data were taken after 60 DAT at an interval of 10 days. For data collection of days to flower initiation, the number of days from transplanting was counted until the first visible flower bud appeared and for the 50% of bud emerges, dates were recorded on the days when 50% of the plant in the plot showed flower bud initiation.

2.5. Statistical analysis

Data was entered and organized using Microsoft Excel. The effects of potassium doses and moisture regimes on the studied variables were first subjected to the Shapiro-Wilk test to determine the normal distribution and analyzed through two-way Analysis of Variance (two-way ANOVA) to identify the significance of the results using the statistical software R version 4.4.0 (package: Agricolae). For mean comparison, the Least Significant Difference (LSD) test was employed to find significant mean differences between treatments at a significance level of 5%. Data visualization was also done using Microsoft Excel

3. RESULTS AND DISCUSSION

3.1. Plant height

Potassium doses and soil moisture regimes significantly influenced plant height (Table 2 and Figure 1). The application of potassium levels gave significant ($p \leq 0.001$) differences for plant height. Application of 120 kg/ha K produced the highest plant height (36.66 cm, 61.61 cm and 81.27 cm at 25, 40, and 55 DAT, respectively), followed by 160 kg/ha K whereas, 40 kg/ha K resulted in the lowest plant height. Similarly, 100% of FC exhibited significantly greater heights at all growth stages compared to 60% FC. K doses and soil moisture regimes interaction also showed a significant effect on plant height (highest at the interaction of 120 kg/ha K under 100% of FC). Since K plays the vital role in the activation of enzymes, cell expansion, photosynthesis, nitrogen use, and water balance, it favors stem elongation for plant height (Hasanuzzaman et al., 2018). On the other hand, adequate water supply helps in maintaining cell turgor, supporting translocation of photosynthates and regulating plant hormones, which can enhance vegetative growth (Kudoyarova et al., 2015).

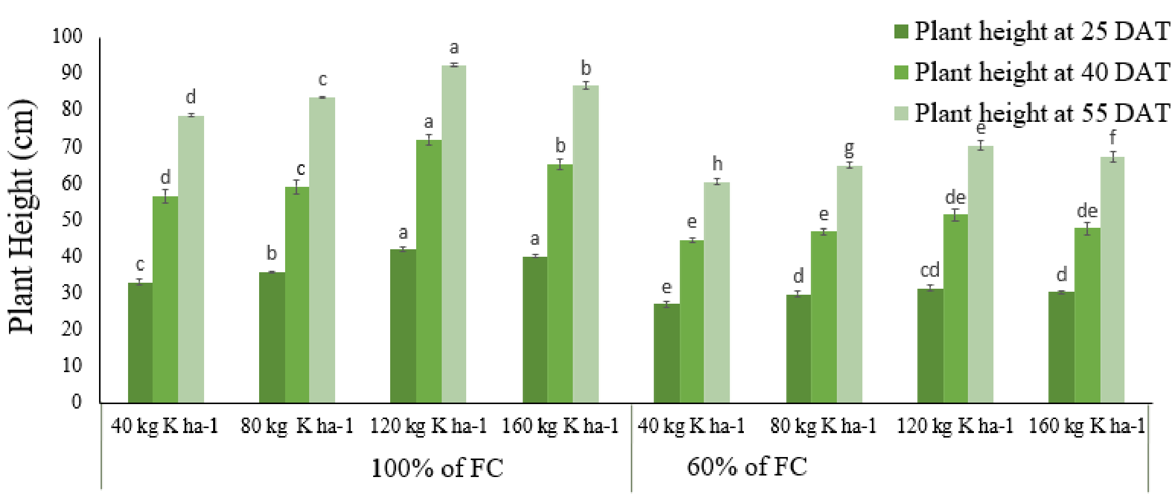

Figure 1: Effect of potassium doses and moisture regimes interaction on plant height

3.2. Stem diameter

Stem diameter increased significantly ($p \leq 0.001$) as K doses increased from 40 kg/ha to 160 kg/ha. The stem diameter was the largest at 160 kg/ha K(0.91 cm), followed by 120 kg/ha K and the smallest at 40 kg/ha. Kanai et al. (2011) suggested that increased potassium enhances stem diameter as it improves water uptake, photosynthesis and anatomical characteristics of the stem. Moisture regimes also significantly affected stem diameter. Plants grown under 100% of FC had significantly larger stem diameters (0.88 cm) than those under 60% of FC (Table 2). Also, plants at 100% FC fully absorb water, which increases the pressure that helps the cells to expand and divide, resulting in thicker stems as new cells develop in the cambial layer (Meng et al., 2017). But the interaction effect of potassium doses and moisture regimes was found to be non-significant.

Table 2: Effect of potassium doses and moisture on plant height and stem diameter of marigold at different days after transplanting.

Treatment	**PH25 (cm)**	**PH40 (cm)**	**PH55 (cm)**	**SD25 (cm)**	**SD40 (cm)**	**SD55 (cm)**
K doses (kg/ha)						
40	29.91^{d}	50.53^{c}	69.40^{d}	0.40^{c}	0.53^{b}	0.79^{c}
80	32.75^{c}	52.95^{c}	74.12^{c}	0.45^{b}	0.61^{b}	0.81^{c}
120	36.66^{a}	61.61^{a}	81.27^{a}	0.48^{a}	0.70^{a}	0.85^{b}
160	35.16^{b}	56.95^{b}	76.93^{b}	0.50^{a}	0.78^{a}	0.91^{a}
LSD (0.05)	1.411	3.391	1.107	0.026	0.831	0.036
SEM (±)	0.116	0.279	0.091	0.002	0.006	0.002
Significance	***	***	***	***	***	***
Moisture regimes						
60% of FC	29.56^{b}	47.56^{b}	65.66^{b}	0.36^{b}	0.61^{b}	0.80^{b}
100% of FC	37.68^{a}	63.23^{a}	85.20^{a}	0.55^{a}	0.70^{a}	0.88^{a}
LSD (0.05)	0.998	2.397	0.783	0.018	0.058	0.025
SEM (±)	0.164	0.395	0.129	0.003	0.009	0.004
Significance	***	***	***	***	**	***
Interaction						
LSD (0.05)	1.996	4.795	1.566	0.037	0.117	0.051
SEM (±)	0.082	0.197	0.064	0.001	0.004	0.002
Significance	**	*	**	.		
CV, %	3.39	4.94	1.185	4.649	10.156	3.467
Grand Mean	33.62	55.4	75.43	0.46	0.66	0.84

Note: PH25: Plant height at 25 DAT, PH40: Plant height at 40 DAT, PH55: Plant height at 55 DAT, SD25: Stem diameter at 25 DAT, SD40: Stem diameter at 40 DAT, SD55: Stem diameter at 55 DAT, LSD: Least Significant Difference, SE m = Standard error of mean, CV: Coefficient of variation, '***', '**', '*', '.' and ' ' indicates significant at 0.001, 0.01, 0.05, 0.1 and 1 probability level respectively and value with same letters on column are not significantly different at 5% DMRT.

3.3. Primary and secondary branches number

The number of primary and secondary branches varied significantly with the individual and interactive effects of potassium doses and moisture regimes. The highest number of primary and secondary branches was recorded at 120 kg/ha K and the lowest ones were again observed at the 40 kg/ha dose. Plants under 100% of FC produced significantly higher number of primary branches at 55 DAT (25.43) and secondary branches at 55 DAT (16.67) compared to those under 60% of FC (Table 3). According to Silva et al. (2021), an increase in potassium doses improves CO_2 assimilation, water use efficiency, and root branching patterns in plants. And sufficient moisture supports an increase in the number of branches, by improving physiological processes such as chlorophyll content, leaf area, and overall biomass production (Wadleigh & Ayers, 1945).

3.4. Plant canopy spread

The significant differences were observed in the individual effects of potassium and moisture on plant canopy; however, they did not show significant effects for their interaction (Table 3). The plant canopy spreads were significantly larger at 120 kg/ha K (59.11 cm). Potassium plays a pivotal role in promoting the production and movement of growth hormones like auxins, which promote lateral branching and leaf development. As a result, plants can capture more sunlight, which enhances their ability to photosynthesize (Xie et al., 2020). Similar findings were supported by Hasanuzzaman et al. (2018). The plants applied with 100% of FC had significantly larger canopy spreads (27.01 cm, 42.59 cm and 57.93 cm) than the other one. Through sufficient moisture, the plant tissues hydrate better. This promotes cell expansion and root development, which supports increased nutrient uptake, further driving shoot growth and canopy spread (Banik et al., 2024).

Table 3: Effect of potassium doses and moisture on number of primary branches, secondary branches and plant canopy spread of marigold at different days after transplanting

Treatment	PB25	PB40	PB55	SB40	SB55	PC25 (cm)	PC40 (cm)	PC55 (cm)
K doses (kg/ha)								
40	5.16^{c}	19.33^{c}	21.30^{c}	8.58^{c}	14.45^{d}	21.50^{c}	37.12^{c}	51.96^{c}
80	5.65^{b}	20.96^{b}	22.61^{b}	9.00^{b}	15.21^{c}	23.75^{bc}	39.71^{b}	54.65^{bc}
120	6.58^{a}	22.53^{a}	25.38^{a}	9.53^{a}	16.78^{a}	28.08^{a}	42.80^{a}	59.11^{a}
160	6.43^{a}	22.26^{a}	23.35^{b}	9.13^{b}	15.91^{b}	24.48^{b}	41.55^{a}	56.00^{b}
LSD (0.05)	0.231	0.495	0.763	0.161	0.276	2.652	1.688	2.743
SEM (±)	0.019	0.041	0.062	0.013	0.022	0.218	0.139	0.226
Significance	***	***	***	***	***	***	***	***
Moisture Regimes								
60% of FC	5.15^{b}	19.98^{b}	20.89^{b}	8.60^{b}	14.5^{b}	21.89^{b}	38.00^{b}	52.93^{b}
100% of FC	6.76^{a}	22.56^{a}	25.43^{a}	9.51^{a}	16.67^{a}	27.01^{a}	42.59^{a}	57.93^{a}
LSD (0.05)	0.163	0.350	0.539	0.114	0.195	1.875	1.194	1.940
SEM (±)	0.027	0.057	0.089	0.018	0.032	0.309	0.196	0.319
Significance	***	***	***	***	***	***	***	***
Interaction								
LSD (0.05)	0.370	0.700	1.079	0.228	0.391	3.751	2.388	3.880
SEM (±)	0.013	0.028	0.044	0.009	0.016	0.154	0.098	0.159
Significance	**	**	*	***	*			
CV, %	3.139	1.880	2.661	1.438	1.434	8.76	3.384	3.99
Grand Mean	5.95	21.27	23.16	9.06	15.59	24.45	40.29	55.43

Note: PB25: Number of primary branches at 25 DAT, PB40: Number of primary branches at 40 DAT, PB55: Number of primary branches at 55 DAT, SB40: Number of secondary branches at 40 DAT, SB55: Number of secondary branches at 55 DAT, PC25: Plant canopy spread at 25 DAT, PC40: Plant canopy spread at 40 DAT and PC55: Plant canopy spread at 40 DAT.

3.5. Days to early flower initiation

There was a significant influence of potassium and soil moisture regimes on the days to flower initiation. Application of 120 kg/ha K showed the earliest flowering (28.05 days) and 50% flower initiation (36.00 days), followed by 80 kg/ha. Similarly, plants treated with 100% of FC resulted in significantly earlier flowering (30.58 days) and reached 50% flower initiation sooner (39.83 days) than those at 60% of FC. The interaction of 120 kg/ha K with 100% FC significantly accelerated flowering (28.00 days) and resulted in earlier days to 50% flower initiation (Table 4). This might be due to plant canopy spread at 55 DAT potassium-mediated enzymes being activated along with optimal cellular hydration, which together accelerate meristematic activity and floral primordia development (Singh & Rao, 2005).

3.6. Flower diameter

The flower diameter was also significantly influenced by different levels of potassium and moisture. Significantly, 120 kg/ha K recorded the larger diameter of the flower (6.54 cm), followed by 80 kg/ha (6.19 cm), whereas the smaller flowers were found at 40 kg/ha K. Similarly, plants grown at 100% of FC produced flowers with a larger diameter than those grown at 60%. The interaction between them also resulted in a significant effect ($p \leq 0.05$) (Table 4).

3.7. Number of flowers

Plants treated with 120 kg/ha K produced significantly higher number of flowers (30.45), followed closely by 160 kg/ha K and the lowest were observed at 40 kg/ha K. Plants grown under 100% of FC significantly outperformed those under 60% of FC again, with statistically significant differences. There were significant interactions ($p < 0.05$) between potassium doses and moisture regimes for the number of flowers per plant (Table 4 and Figure 2). A similar result was found by Sanghamitra et al. (2015), who concluded that higher potassium levels are directly proportional to the number of flowers in marigold plants. This is because potassium improves nutrient uptake, helps in photosynthesis, and carbohydrate transport to flower buds. It also plays a key role in regulating enzymes and hormones like auxins that promote flowering, resulting in an increased number of blooms (Teja et al., 2017). The increased soil moisture leads to more efficient nutrient transport and higher turgor pressure, which stimulates bud formation and results in an increase in the number of flowers (Martin, 1940).

3.8. Flower fresh weight and yield

The potassium dose of 120 kg/ha recorded significantly higher flower weight (8.83 gm) and yield (11.11 t/ha), which were statistically similar to those of 80 kg/ha. Similarly, the lowest flower weight and yield was found at 40 kg/ha K. 100% of FC produced a significantly higher flower weight (6.27 gm) and yield (6.27 t/ha) than those under 60% of FC. A similar result by Massoud et al. (2014), which showed that irrigating marigold plants resulted in maximum fresh and dry weights, while less irrigated marigold plants produced the lowest weight. The interaction effect was also significant, with 120 kg/ha K and 100% of FC producing the maximum flower fresh weight (11.67 gm) and yield (11.52 t/ha) (Table 4). Potassium enhances water uptake and retention in marigold cells while proper moisture ensures optimal nutrient transport, together leading to increased flower fresh weight through better cell expansion and metabolic functions (Singh & Rao, 2005).

Table 4: Effect of potassium doses and moisture on yield attributes of marigold at different days after transplanting

Treatment	DFI	DFI_{50}	FH60	FH70	FW (gm)	FD (cm)	Yield (t/ha)
K doses (kg/ha)							
40	34.33^{b}	45.00^{c}	15.45^{c}	15.46^{d}	5.30^{c}	5.42^{d}	9.03^{c}
80	33.30^{b}	42.50^{b}	23.30^{a}	26.06^{b}	8.08^{ab}	6.19^{b}	10.3^{ab}
120	28.50^{a}	36.00^{a}	23.97^{a}	30.45^{a}	8.83^{a}	6.54^{a}	11.11^{a}
160	34.66^{b}	44.33^{c}	20.60^{b}	23.16^{c}	6.76^{bc}	5.76^{c}	9.98^{bc}
LSD (0.05)	1.62	1.98	1.72	1.67	1.72	0.33	0.35

SEM (±)	0.13	0.16	0.14	0.13	0.14	0.27	0.11
Significance	*	**	*	**	**	***	**
Moisture regimes							
60% of FC	34.33[b]	44.08[b]	19.6[b]	22.43[b]	5.80[b]	6.27[b]	8.60[b]
100% of FC	30.58[a]	39.83[a]	22.06[a]	25.14[a]	8.68[a]	5.68[a]	10.80[a]
LSD (0.05)	1.14	1.40	1.22	1.18	1.21	0.23	0.22
SEM (±)	0.18	0.23	0.20	0.19	0.20	0.37	0.16
Significance	*	**	*	**	**	***	**
Interaction							
LSD (0.05)	2.29	2.80	2.44	2.36	2.43	0.47	0.81
SEM (±)	0.75	0.92	0.80	0.78	0.80	0.55	0.61
Significance	**	*	*	*	*	*	*
CV, %	4.04	3.82	6.69	5.68	19.17	4.49	3.20
Grand Mean	32.4	41.95	20.84	23.78	7.24	5.98	9.85

Note: DFI: Days to flower initiation, DFI_{50}: 50% of bud emergence, FH60: Flower heads/plant at 60 DAT, FH70: Flower heads/plant at 70 DAT, FW: Flower fresh weight and FD: Flower diameter

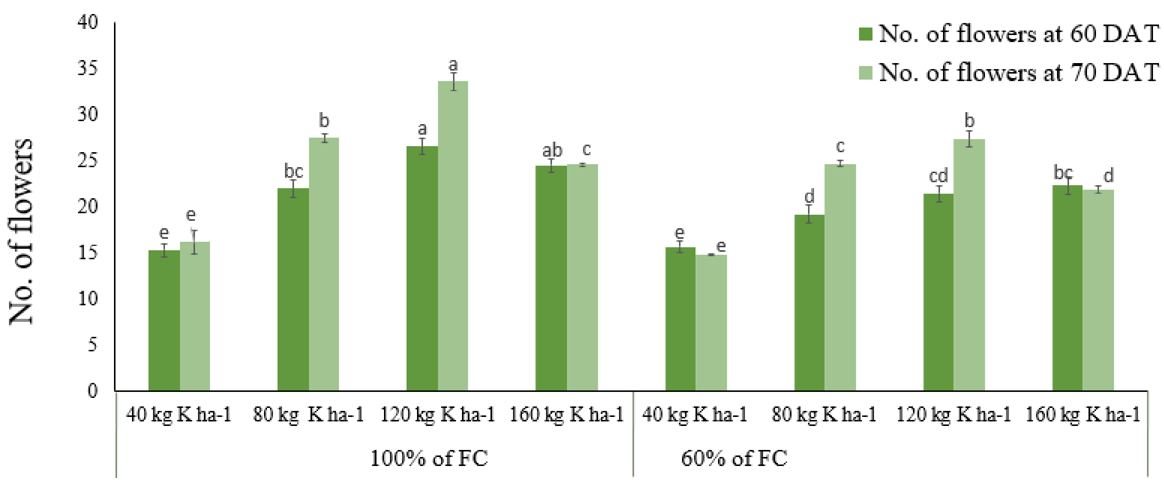

Figure 2: Effect of potassium doses and moisture regimes interaction on the number of flowers

4. CONCLUSION

Based on the study, it was found that potassium doses and soil moisture regimes had significant and consistent effects on the growth, flowering, and yield attributes of African marigold. The application of 120 kg/ha K significantly increased all the parameter, while 160 kg/ha K showed comparable but not consistently superior effects but was able to give significantly larger stem diameter. And 40 kg/ha K resulted in inferior growth and yield attributes. All the measured parameters were significantly higher at 100% of FC. Similarly, the synergistic effects of 120 kg/ha K under 100% of FC had a significant effect on overall parameters. Thus, it can be concluded that the application of 120 kg/ha K with 100% of FC results in better marigold flower production. However, further multi-seasonal and multi-locational trials of the experiment are required before making broad recommendations to farmers.

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