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Influence of phosphorous and potassium nutrition on growth, yield and fruit quality of Gala Mast apple

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ABSTRACT

The present study was conducted in the experimental field of the Division of Fruit Science, SKUAST-Kashmir, Shalimar Campus, Srinagar (Jammu and Kashmir, India) on four-year-old Gala Mast apple grafted on MM106 rootstock under high-density plantation (3m × 3m) to standardize the optimum dose of phosphorous and potassium. Sixteen treatment combinations of four levels of phosphorous (25 g, 50 g, 75 g, and 100 g/tree) and potassium (150 g, 200 g, 250 g, and 300 g/tree) were tested. As a result, the maximum increase in tree height (55.89 cm), tree circumference (2.31 cm), annual shoot extension (47.13 cm), leaf area (42.00 cm^2), fruit length (6.52 cm), fruit diameter (7.31 cm), fruit weight (168.26 g), fruit volume (185.48 cm^3), yield (6.85 kg/tree), total soluble solids (15.85°B), total sugars (13.17 %), ascorbic acid (5.89 mg/100 g), and anthocyanin content (9.27 mg/100 g) were observed with the application of phosphorous @ 100 g + potassium @ 300 g. Highest fruit firmness (9.81 kg/cm^2) was recorded when phosphorous @ 100 g + potassium @ 150 g was applied. In contrast, minimum acidity (0.197 %) and maximum TSS/acid (76.47) ratio were recorded by using phosphorous @ 25 g + potassium @ 300 g. Therefore, it can be concluded that phosphorous @ 100 g/tree in combination with potassium @ 300 g/tree proved most economical and effective in improving apple cv's growth, yield, and quality.

Keywords: *Malus* × *domestica* Borkh, fertilizer doses, high density planting, MM 106

INTRODUCTION

Jammu and Kashmir produces 18,82,319 MT of apple, approximately 70 per cent of the total production of apples in India with a productivity 11.42 MT/ha (Anonymous, 2) which is very low as compared to the New Zealand (56.72 MT/ha) and Chile (50.08 MT/ha). High density orcharding appears to be the most appropriate answer and need of the hour to overcome low productivity and long gestation period for early returns (Goswami *et al.,* 6). However, under high density orcharding, the enhanced production is possible only, if greater attention is paid to improve the efficiency of input use, particularly mineral nutrients. Mineral nutrients form an important part of plants and play an important role in their growth and development. A vast array of reports is available on the importance of nitrogen element in fruits. However, nutrition of fruit crops with phosphorus and potassium has received little attention (Nachtigall and Dechen, 11).

Phosphorus helps in the synthesis of organic phosphoric compounds which is essential for synthesis of proteins and carbohydrates. It strengthens the root system and is required for the expansion of roots in the soil. It is involved in energy transfer, the maintenance of cell membranes and as a bridging element for genetic information (Lambers *et al.,* 10). It has a direct effect on yield and tree health, but is also important in determining fruit size, firmness, colour and storage potential. Potassium is a primary nutrient that plays a major role in achieving high quality fruit and maximum yields. Apple trees absorb potassium in greater amount than any other nutrient (Brunetto *et al.*, 4). Insufficient potassium levels can cause abnormalities in plants like poor root development, stunted growth, less fruit colour and poor fruit quality (Brunetto *et al.*, 4). It is essential for the manufacture and translocation of sugars and also plays an important role in the uptake and transportation of water by tree (Jain, 7). Keeping in view the importance of phosphorus and potassium on high density plantation of apple, the present experiment was conducted to optimize the doses of phosphorous and potassium nutrients to achieve the desired tree growth, fruit yield and quality of apple cv. Gala Mast under high density plantation.

MATERIALS AND METHODS

The present investigation was carried out on four year old apple cv. Gala Mast grafted on MM106 planted at experimental field of Division of Fruit Science at SKUAST-Kashmir under high density plantation with a spacing of 3m × 3 m. The maximum

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and minimum temperature during the experimental period ranged between 18.1-32.0°C and 4.42-17.7°C with a mean relative humidity of 43.90 per cent.

The experiment was laid out on forty eight uniform trees with factorial randomized complete block design, and replicated thrice with one tree per replication. Nitrogen, phosphorous and potassium were applied through Urea, DAP and MOP fertilizers, respectively. All the trees received a uniform dose of nitrogen @ 100 g N/tree. The corresponding doses of phosphorus (P_2O_5) and potassium (K_2O) were applied as per the treatment combinations (Table 1). First dose of nitrogen, full dose of phosphorus and half dose of potassium were applied 3 weeks before expected bloom. The second dose of nitrogen and remaining half dose of potassium were applied 3 weeks after fruit set. The third and final split dose of nitrogen was applied in the last week of June.

Tree height was measured with the help of the measuring pole, whereas tree girth was measured with the help of measuring tape 15 cm above the ground level before the start and after the completion of the experiment. Annual extension growth of the current season on four different randomly shoots was recorded and averaged. Leaf area was calculated with help of automatic leaf area meter (221 Systronics). Yield per tree was calculated by weighing whole fruits from a single plant.

Ten fruits were randomly taken for all the physio-chemical characters. Fruit weight was determined with the help of digital weighing balance, however fruit length and diameter were determined using a digital Vernier calliper. Fruit flesh firmness was determined with the help of a digital Effegi pressure tester plunger. Total soluble solids were determined by using digital hand refractometer, whereas acidity was measured through titration method in terms of malic acid. Total sugars was determined as per the standard procedures (AOAC, 3). Ascorbic acid was measured by titrating the samples against 2,6-dichlorophenolindophenol dye. Anthocyanin was estimated using pH differential methods suggested by Kaur and Dhillon (9).

Data generated from these investigations were appropriately computed, tabulated and statistically analyzed as per the procedure given by Snedecor and Cochran (17). The level of significance was tested for different variables at 5 per cent level of significance.

RESULTS AND DISCUSSION

Perusal of data presented in the Table 2 revealed significant influence of nutrient doses on different growth and foliage characters of apple tree. The highest incremental tree height (55.89 cm) was observed in the treatment combination of P_4K_4 i.e. phosphorous applied @ 100 g/tree + potassium @ 300 g/tree, which was statistically at par with P_3K_4 (55.36 cm) treatment. The lowest increase in tree height (37.16 cm) was observed in P_1K_1 treatment. Interaction effect of phosphorous and potassium showed a significant effect on tree girth. Maximum increment in tree girth (2.31 cm) was recorded in the treatment combination P_4K_4 (100 g P/tree + 300 g K/tree), which was statistically at par with P_3K_4, however, it was lowest in P_1K_1 (0.23 cm) treatment. The longest annual shoot extension was recorded in P_4K_4 (47.13 cm) having similarity statistically with P_3K_4 (46.91 cm), whereas it was lowest in treatment P_1K_1 (33.55 cm). The highest (42.00 cm^2) and lowest (28.59 cm^2) leaf area were recorded with the application of phosphorous applied @ 100 g/tree + potassium @ 300 g/tree (P_4K_4) and phosphorous applied @ 25 g/tree + potassium @ 150 g/tree (P_1K_1), respectively. Increase in phosphorous content improves growth characters because phosphorous as a constituent of nucleic acids (DNA and RNA) stimulates cell division, and is an important regulator of meristematic activity. It plays an important role in protein synthesis through ATP and nucleic acids (Jain, 7). However, increase in growth characters due to high potassium rate can be attributed to the fact that potassium is an activator of enzymes involved in synthesis of certain peptide bonds during protein synthesis and plays an important role in photosynthesis and translocation of carbohydrates. Present findings are in agreement with the findings of Kaack and Pedersen (8) and Wojcik and Wojcik (18).

A significant influence of P and K was noticed on physical characters of Gala Mast apple fruit (Table 3).

Table 1. Treatment combinations.

Potassium (K) / Phosphorous (P)	K_1	K_2	K_3	K_4
P_1	$P_{25}K_{150}$	$P_{25}K_{200}$	$P_{25}K_{250}$	$P_{25}K_{300}$
P_2	$P_{50}K_{150}$	$P_{50}K_{200}$	$P_{50}K_{250}$	$P_{50}K_{300}$
P_3	$P_{75}K_{150}$	$P_{75}K_{200}$	$P_{75}K_{250}$	$P_{75}K_{300}$
P_4	$P_{100}K_{150}$	$P_{100}K_{200}$	$P_{100}K_{250}$	$P_{100}K_{300}$

Table 2. Effect of different levels of phosphorous and potassium on growth characters of apple cv. Gala Mast.

Potassium / Phosphorous	Incremental tree height (cm)				Mean	Incremental tree girth (cm)				Mean	Annual shoot extension (cm)				Mean	Leaf area (cm²)				Mean
	K_1	K_2	K_3	K_4		K_1	K_2	K_3	K_4		K_1	K_2	K_3	K_4		K_1	K_2	K_3	K_4	
P_1	37.16	37.95	40.25	42.38	39.43	0.23	0.36	0.46	0.66	0.43	33.55	34.21	36.96	38.69	35.85	28.59	30.79	33.00	34.51	31.72
P_2	41.13	43.04	45.35	48.04	44.39	0.30	0.54	0.75	1.04	0.66	35.35	38.30	39.70	40.82	38.54	30.67	33.83	36.87	39.60	35.24
P_3	46.68	49.15	52.55	55.36	50.93	1.05	1.44	1.92	2.29	1.67	37.76	41.32	44.60	46.91	42.65	32.07	35.13	38.78	41.76	36.93
P_4	47.01	48.64	53.10	55.89	51.16	1.05	1.47	1.95	2.31	1.69	37.91	41.50	44.76	47.13	42.82	32.32	35.37	38.97	42.00	37.16
Mean	42.99	44.69	47.81	50.42		0.66	0.95	1.27	1.57		36.14	38.83	41.50	43.39		28.59	30.79	33.00	34.51	
$CD_{(0.05)}$																				
P		0.61					0.05					0.24					0.35			
K		0.61					0.05					0.24					0.35			
P × K		1.22					0.09					0.48					0.70			

P_1: 25 g, P_2: 50 g, P_3: 75 g, P_4: 100 g K_1: 100 g, K_2: 200 g, K_3: 250 g, K_4: 300 g

Table 3. Effect of different levels of phosphorous and potassium on yield and fruit physical characteristics of apple cv. Gala Mast.

Potassium / Phosphorous	Fruit length (cm)				Mean	Fruit diameter (cm)				Mean	Fruit weight (g)				Mean	Fruit yield (kg/plant)				Mean
	K_1	K_2	K_3	K_4		K_1	K_2	K_3	K_4		K_1	K_2	K_3	K_4		K_1	K_2	K_3	K_4	
P_1	5.93	5.97	6.03	6.06	5.99	6.74	6.79	6.85	6.88	6.82	145.26	147.49	150.28	152.39	148.86	5.49	5.59	5.64	5.71	5.61
P_2	6.02	6.05	6.13	6.18	6.09	6.86	6.88	6.94	6.99	6.92	149.66	152.30	156.85	159.47	154.57	5.83	5.84	6.10	6.15	5.98
P_3	6.06	6.13	6.35	6.46	6.25	6.88	6.95	7.15	7.28	7.07	152.68	157.53	163.14	167.37	160.18	6.34	6.41	6.52	6.81	6.52
P_4	6.05	6.13	6.40	6.52	6.28	6.87	6.97	7.20	7.31	7.09	153.02	158.47	163.94	168.26	160.92	6.35	6.45	6.56	6.85	6.55
Mean	6.02	6.07	6.23	6.30		6.84	6.89	7.03	7.12		150.15	153.95	158.55	161.87		6.00	6.07	6.20	6.38	
$CD_{(0.05)}$																				
P		0.07					0.07					1.58					0.06			
K		0.07					0.07					1.58					0.06			
P × K		0.14					0.14					3.16					0.13			

P_1: 25 g, P_2: 50 g, P_3: 75 g, P_4: 100 g K_1: 100 g, K_2: 200 g, K_3: 250 g, K_4: 300 g

The highest fruit length (6.52 cm) and fruit diameter (7.31 cm) was recorded in the treatment P_4K_4 which did not differ statistically with treatment P_3K_4 (6.46 cm) and P_4K_3 (6.40 cm) for fruit length and treatment P_3K_4 (7.28 cm) and P_4K_3 (7.20 cm) for fruit diameter. Treatment P_4K_4 registered the maximum fruit weight (168.26 g) which was statistically at with P_3K_4 (167.37 g) treatment however minimum fruit weight was recorded in the treatment P_1K_1 (145.26 g). Raese (14) also reported an increase in fruit size and weight with increased level of phosphorous application. Increase in fruit size by potassium application can be attributed to the role of potassium in cell division, elongation and translocation. Cell elongation depends on turgor and optimum turgor requires sufficient potassium ions (Ragel *et al.*, 15). The results are in agreement with the findings of Anjum *et al.* (1). Interaction studies among phosphorous and potassium showed significant results with respect to fruit volume (Fig. 1). Treatment P_4K_4 exhibited the maximum fruit volume (185.48 cm^3) which was statistically at par with treatment combination of P_3K_4 (185.28 cm^3), P_4K_3 (185.28 cm^3) and P_3K_3 (185.28 cm^3) however minimum fruit volume (168.43 cm^3) was recorded in P_1K_1 treatment.

The highest fruit firmness (9.81 kg/cm^2) was noticed with P_4K_1 (100 g P/tree + 150 g K/tree) which was statistically at par with P_3K_1, P_4K_2 and P_3K_2 (Fig. 2), while it was lowest (8.39 kg/cm^2) with the application of phosphorous @ 25 g/ tree + potassium @ 300 g/tree (P_1K_4). Increase in firmness with higher levels of phosphorous is because of the role of phosphorous in the creation and stability of cell walls in fruit (Neilsen and Neilsen, 13) however higher potassium levels decrease the calcium content of fruits which might have resulted in reduced content of water insoluble pectic substances. Calcium is a constituent of the middle lamella of cell wall and therefore the decrease in calcium content reduces fruit firmness. The findings are in agreement with Kaack and Pedersen (8). Dilmaghani *et al.* (5) also observed that negative correlations existed between K/Ca ratio and apple fruit firmness at harvest.

The interaction effect of phosphorous and potassium (P ×K) presented in Table 3 produced a significant effect on fruit yield. The treatment P_4K_4 (100 g P/tree and 300 g K/tree) proved most productive (6.85 kg/tree), which was statistically at par with P_3K_4, while it was lowest in the treatment P_1K_1 (5.49 kg/tree). Application of phosphorous improves flowering and fruit set, while potassium has been reported to have a positive effect on yield as it promotes photosynthesis, speeds up the flow of assimilates, intensifies the storage of assimilates and favours the production of proteins by generation of ATP (Ragel *et al.*, 15). The positive influence of phosphorous and potassium on apple fruit yield have also been reported earlier by Nava and Dachen (12) and Wojcik and Wojcik (18) .

Total soluble solids was significantly influenced with the application of phosphorous and potassium (P × K), however, it failed to affect acidity and TSS/acid ratio significantly (Table 4). Treatment P_4K_4 resulted the highest total soluble solids (15.85°B), which was statistically at par with P_3K_4; however, lowest TSS was recorded in control treatment (13.27°B). The lowest and highest acidity was recorded in the treatment P_1K_4 (0.19 %) and P_4K_1 and P_3K_1 (0.25 in each %), respectively, whereas highest and lowest TSS/acid ratio was recorded in the treatment combination of P_1K_4 (76.47) and P_3K_1 (54.73), respectively. The treatment combination P_4K_4 resulted the highest content of total sugars (13.17 %) which was closely followed by P_3K_4 (13.09 %) without having significant difference, however , it was lowest in the P_1K_1 treatment (10.03

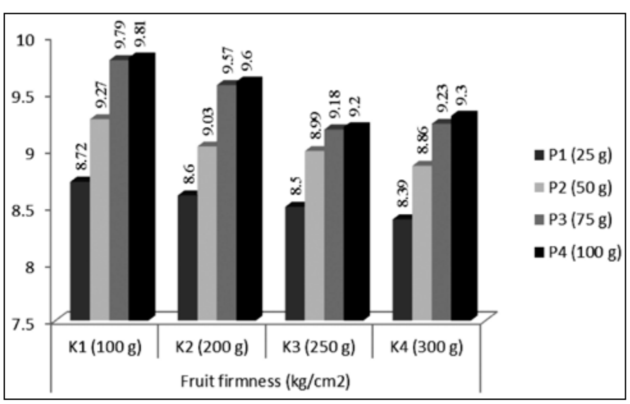

Fig. 1. Effect of different levels of phosphorous and potassium on fruit firmness of apple cv. Gala Mast.

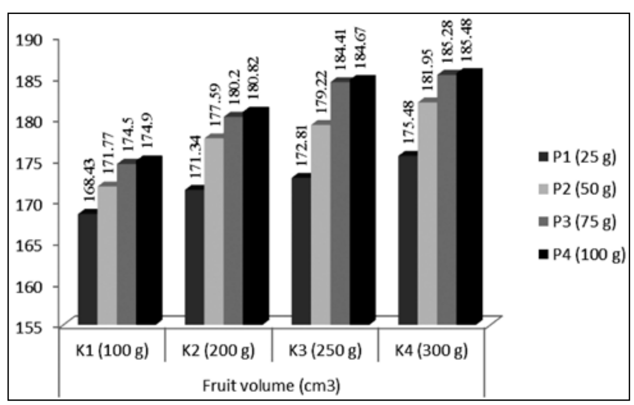

Fig. 2. Effect of different levels of phosphorous and potassium on fruit volume of apple cv. Gala Mast.

Table 4. Effect of different levels of phosphorous and potassium on fruit chemical characteristics of apple cv. Gala Mast

Potassium / Phosphorous	Total soluble solids (°B)				Mean	Acidity (%)				Mean	TSS/acid ratio				Mean
	K_1	K_2	K_3	K_4		K_1	K_2	K_3	K_4		K_1	K_2	K_3	K_4	
P_1	13.27	13.61	14.05	14.53	13.86	0.214	0.206	0.197	0.190	0.202	62.12	66.24	71.33	76.47	69.04
P_2	13.41	13.91	14.63	15.43	14.34	0.230	0.223	0.214	0.207	0.218	58.32	62.50	68.36	74.71	65.97
P_3	13.68	14.27	14.90	15.79	14.66	0.250	0.242	0.237	0.228	0.239	54.73	58.99	62.98	69.25	61.49
P_4	13.74	14.23	14.98	15.85	14.70	0.250	0.243	0.238	0.230	0.240	54.97	58.50	62.94	68.91	61.33
Mean	13.52	14.00	14.64	15.40		0.236	0.228	0.221	0.214		57.53	61.55	66.40	72.33	
$CD_{(0.05)}$															
P			0.16					0.003					1.07		
K			0.16					0.003					1.07		
P × K			0.32					NS					NS		

P_1: 25 g, P_2: 50 g, P_3: 75 g, P_4: 100 g K_1: 100 g, K_2: 200 g, K_3: 250 g, K_4: 300 g

Table 5. Effect of different levels of phosphorous and potassium on fruit chemical characteristics of apple cv. Gala Mast

Potassium / Phosphorous	Total sugars (%)				Mean	Ascorbic acid (mg/100 g)				Mean	Anthocyanin (mg/100 g)				Mean
	K_1	K_2	K_3	K_4		K_1	K_2	K_3	K_4		K_1	K_2	K_3	K_4	
P_1	10.03	10.54	11.05	11.47	10.77	4.17	4.46	4.63	4.82	4.52	7.08	7.74	7.87	8.51	7.80
P_2	10.47	10.89	11.49	12.05	11.22	4.35	4.58	4.91	5.26	4.77	7.20	7.87	8.34	8.83	8.06
P_3	10.77	11.40	12.14	13.09	11.85	4.53	4.83	5.37	5.89	5.16	7.37	8.09	8.71	9.23	8.35
P_4	10.83	11.42	12.17	13.17	11.89	4.53	4.85	5.39	5.89	5.16	7.41	8.12	8.71	9.27	8.37
Mean	10.52	11.06	11.71	12.44		4.39	4.68	5.08	5.46		7.27	7.95	8.40	8.96	
$CD_{(0.05)}$															
P			0.18					0.09					0.16		
K			0.18					0.09					0.16		
P × K			0.36					0.18					0.32		

P_1: 25 g, P_2: 50 g, P_3: 75 g, P_4: 100 g K_1: 100 g, K_2: 200 g, K_3: 250 g, K_4: 300 g

%) (Table 5). Phosphorous plays an effective role in the process of photosynthesis which ultimately led to the accumulation of larger amount of sugars and thereby increasing TSS content. Increase in acidity may be due to the increase in synthesis of nucleic acids and improved energy supply through adenosine phosphates for the synthesis of organic acids. Increase in total sugars may also be due to the role of potassium in increasing the rate of hydrolysis of polysaccharides into monosaccharides. These results are in conformity with results obtained by Kaack and Pedersen (8).

Ascorbic acid and anthocyanin content were significantly influenced with the combined application of phosphorous and potassium (Table 5). Significantly highest ascorbic acid was recorded in the treatment combination of P_4K_4 and P_3K_4 (5.89 mg/100 g in each), whereas lowest ascorbic acid was recorded in the treatment P_1K_1 (4.17 mg/100 g). The beneficial effect of potassium on ascorbic acid probably resulted from a combination of improved carbon dioxide assimilation, assimilates translocation to fruits and increased enzyme activation and substrate availability for ascorbic acid biosynthesis. Similar results were earlier reported by Sharma *et al.* (16). Treatment P_4K_4 tended to increase the anthocyanin content (9.27 mg/100 g), which was statistically at par with treatment P_3K_4 , however, it was lowest in the treatment P_1K_1 (7.08 mg/100 g). Phosphorous has been associated with the production of phenylalanine ammonia-lyase and increases the sugar availability through its effect on photosynthesis. This explains the increase in anthocyanin content with increase in phosphorous dose. Role of potassium in sugar translocation as these sugars are required for synthesis of anthocyanin. Moreover potassium acts as cofactor in activation of specific enzymes that are required for anthocyanin formation in anthocyanin pathway. Increase in anthocyanin content with phosphorous (Wojcik and Wojcik, 18) and potassium (Anjum *et al.*, 1) application has earlier been reported in apple.

From the present study, it is concluded that application of phosphorous @ 100 g and potassium @ 300 g significantly enhanced the growth parameters, yield and physico-chemical parameters of Gala Mast apple/MM-106.

AUTHORS' CONTRIBUTION

Conceptualization of research (UI, MMM, IB); Designing of the experiments (UI, IB); Contribution of experimental materials (IB, MHC); Execution of field/lab experiments and data collection (IF, AK); Analysis of data and interpretation (IF, AK); Preparation of manuscript (UI, AK)

DECLARATION

The authors declare that they have no conflict of interests.

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