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Full Length Research Paper

Effect of Level of Phosphorus and Mulching on Growth and Yield of Tomato (*Lycopersicon lycopersicum* L.)

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A field experiment was conducted at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh to investigate the effect of different levels of phosphorus and mulches on growth, yield attributes and yield of tomato *cv.* Roma VF. The experiment was laid out in two-factor randomized complete block design with three replications. The highest plant height (56.14 cm), flower cluster number (22.39 per plant), flower number (99.01 per plant), fruit number (31.57 per plant), fruit length (6.95 cm), fruit diameter (4.33 cm), single fruit weight (60.23 g), fruit weight per plant (1.91kg) and fruit yield per hectare (62.39 t/ha) was recorded in plants applied with 120 kg P/ha followed by 80 kg P/ha. In contrast, low field yield treatment (1.19 kg per plant and 49.70 t/ha) were recorded from the control plant where no phosphorus were applied. Among the mulches, the tallest plant height (54.48 cm), the highest number of leaves (50.15), number of flower clusters per plant (21.71), number of flowers per plant (97.92) and fruits per plant (1.78 kg). The highest yield attributes (fruit length, fruit diameter and single fruit weight) and fruit yield were recorded in water hyacinth mulch followed by rice straw. In conclusion

80 kg P/ha with use of water hyacinth mulch is suitable for maximizing fruit yield of tomato cv. Roma VF.

Keywords: Tomato, Mulching, Phosphorus level and Yield

INTRODUCTION

Tomato (*Lycopersicon lycopersicum* L.) belongs to the family Solanaceae is one of the popular and nutritious vegetable crops all over the world including Bangladesh. It is cultivated in almost all home gardens and also in the field for its adaptability to a wide range of soil and climate in Bangladesh. Tomato ranks third, next to potato and sweet potato, in terms of world vegetables production (FAO, 2005). In Bangladesh, it ranks 2nd which is next to potato (BBS, 2005) and top the list of canned vegetables (Rashid, 2004). Tomato is originated in tropical America (Salunkhe *et al.* 1987) which includes Peru-Ecuador-Bolivia areas of Andes (Kallo, 1986). The total production of tomato in Bangladesh was about 137000 t from 17900 hectares of land with an average yield of 7.65 t/ha (BBS, 2008). It was 69.41 t/ha in USA, 14.27 t/ha in India, 26.13 t/ha in China, 13.25 t/ha in Indonesia and 59.26 t/ha in Japan (FAO, 2005). Tomato is popular fruit vegetable for its nutritional value and diversified use like salad, juice, sauce etc. It contains vitamin A, B and C including calcium and carotene. The amount of nutrient is 1.98 g protein, 320 IU vitamin-A, 1.8 mg iron and 31 mg vitamin-C in 100 g edible tomato (Bose and Som, 1990). Lycopene in tomato is a powerful antioxidant and reduces the risk of prostate cancer (Hossain, 2001).

Phosphorus fertilizer occupies the second most important input after nitrogen for increasing crop production. High level of phosphorus is essential for rapid root development and for good utilization of water and other nutrients by plant. P has pronounced effect on flower cluster production and the number of flower that increases the yield of tomato (Karim, 2005; Zhang et al., 2007). Further many researchers reported that P fertilizer significantly increased the yield of tomato (Groot et al., 2004; Solaiman and Rabbani, 2006; Sarker 2006). The macronutrient fertilizers including phosphorus fertilizer consumption in Bangladesh are still below the level required for normal crop growth and development which resulted lower yield in tomato. To optimize the nutrient supply for proper growth and development of tomato crop, judicious fertilization is essential. Optimum rate of macronutrients including phosphorus not only increases the yield but also increase the quality of tomato (Seno *et al.* 1987).

Mulching is a desirable management practice which is reported to regulate soil temperature, improve soil moisture, suppress weed growth and save labour cost (Patil and Basad, 1972). The practice has been reported to increase yield by creating favorable temperature and moisture regimes in different parts of the world (Ma and Han, 1995). Water is the single factor which directly affects the tomato yield because it contains 94% water. For successful crop about 285 mm water is required especially at flowering, fruit setting and enlargement stage (Anon., 1995). But irrigation facilities are not sufficient in all the regions of the country. Under the situation mulch play an important role in conserving soil moisture. It improves the soil physical conditions by enhancing the biological activity of soil fauna and thus increases the soil fertility (Lal, 1989). Artificial mulches with straw, rice husk, water hyacinth, crop residues or plastic mulch are generally practiced in the production of horticultural crops (Wilhoit et al., 1990). Different types of mulch play an important role in conserving soil Moisture (Suh and kim, 1991). Considering

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the above-stated factors, the present study was undertaken with the following objectives: i) to find out the effect of different phosphorus on growth and yield of tomato; ii) to assess the optimum level of phosphorus for maximizing the fruit yield in tomato; and iii) to determine the suitable mulch for maximum production of tomato.

MATERIALS AND METHODS

The field experiment was carried out at the Horticulture Farm of the Bangladesh Agricultural University, Mymensingh to find out the effect of phosphorus and mulching on the growth and yield of tomato. The soil of the experimental area was sandy loam and belongs to the Old Brahmaputraputra Flood Plain Alluvial Tract (UNDP, 1988) of Agro Ecological Zone 9 (AEZ-9) having non-calcareous soil. The selected site was a medium high land and the pH of the soil was 6.3 with organic matter content of 1.21%. The tomato variety used in the experiment was Roma-VF. This is a high yielding indeterminate type plant and the seeds were collected from Bangladesh Agricultural University, (BAU) Mymensingh. The land selected for nursery beds was well drained and was of sandy loam type soil.

The experiment consisted of two factors: Factor A: Four different levels of phosphorus P_0: 0 kg P/ha, P_1 : 40 kg P/ha, P_2: 80 kg P/ha, P_3 : 120 kg P/ha. Factor B: Mulch M_0: No mulch, M_1: Water hyacinth, M_2: Straw , M_3: Banana leaf. Thus, the experiment consisting of 16 treatment combinations was laid out in randomized complete block design (RCBD) with three replication. The whole field was divided into three blocks each containing 16 plots. In total, there were 48 unit plots. The treatment combinations were randomly assigned to each unit plot so as to allot one treatment combination only one in each block of unit plot was 2.4 m × 1.6 m. The distance between the blocks was 1m and that between plots was 50 cm.

The land for growing the crop was opened with a tractor. Thereafter, it was gradually ploughed and cross-ploughed several times with power tiller. Each ploughing was followed by laddering to break the clods to level the soil. During land preparation, weeds and stubbles of the previous crop were collected and remove from the land. These operations were done to bring the land under a good tilth. The entire quantity of cowdung (10 t/ha) was applied just after opening the land. Urea and TSP were applied as the source of nitrogen and phosphorus respectively, as per treatments. A basal dressing of potassium at 250 kg MP/ha (BARC, 1997) was given to all treatments including the control plots. Urea and MOP were applied in three instalments. Urea and MOP were applied by broad casting four days before transplanting. The fertilizers were mixed thoroughly with soil by hand. TSP was applied as per dose. The second and third doses of Urea and MOP were added as top dressing at 21 and 35 days after transplanting.

Healthy and uniform sized 30 days old seedlings were taken separately from the seed bed and were transplanted in the experimental field maintaining a spacing of 60cm and 40 cm between the rows and plants, respectively. The seed beds were watered before uprooting the seedlings so as to minimize damage to the roots. This operation was carried out during late hours in the evening. The seedlings were watered after transplanting. Shading was provided by pieces of banana leaf sheath for three days to protect the seedling from the direct sun. Seedlings were also grown around the experimental area to do gap filling and to check the border effect. After transplanting the seedlings, various kinds of intercultural operations were accomplished for better growth and development of the plants. When the seedlings were established, the soil around the base of each seedling was pulverized. Gap filling was done by healthy plants from the border whenever it was required. Weeding was accomplished as and whenever necessary to keep the crop free from weeds, for better soil aeration and to break the crust. It also helped in soil moisture conservation. When the plants were well established, staking was given to each plant by daincha *(Sesbania* sp.) sticks to keep them erect. When a few days of staking, as

the plants grew up, the plants were pruned uniformly having single main stem per plant. Two irrigations were given throughout the growing period by watering can. The first irrigation was given 40 days after planting followed by irrigation 20 days after the first irrigation. Mulching was also done after each irrigation at appropriate time by breaking the soil crust. Insect pests: As preventive measure against the insect pests like cut worm, leaf hopper and others; Diazinon 60 EC was applied at the rate of 2 ml/litre. The insecticide application were made fortnightly from a week after transplanting to a week before first harvesting. During foggy weather precautionary measures against disease infestation especially late blight of tomato were taken by spraying Dithane M-45 fortnightly @ 2 g/l. Fruits were harvested at 5 days intervals during maturing and ripening stage. The maturity of the crop was determined on the basis of red colouring of fruits.

Data on the following parameters were recorded form the sample plants during the course of experiment. Ten plants were selected randomly from each plot in such a way that the border effect was avoided for the highest precision. Data were collected in respect of the following parameters. Plant height (cm), Total number of leaves, Days to first flowering, Number of flower cluster per plant, Number of flowers per cluster, Number of flower per plant, Number of fruit per plant, Weight of individual fruit (g), Weight of fruit per plant (kg), Fruit length (cm), Fruit diameter (cm), Fruit yield per hectare.

RESULTS AND DISCUSSION

Effect of levels of phosphorus, mulches and their combined effect on morphological characters of tomato cv. Roma VF

Plant height

The effect of phosphorus levels on plant height at three days after transplanting (DAT) was statistically significant at $P \leq 0.01$ in tomato (Table 1). Results revealed that plant height increased with age. Plant height increased with increasing phosphorus levels up to 120 kg/ha at all growth stages. The tallest plant was recorded in 120 kg P/ha (15.10, 30.99 and 56.14 cm for 30, 45 and 60 DAT, respectively) followed by 80 kg P/ha (14.47, 27.05 and 54.97 cm for 30, 45 and 60 DAT).

In contrast, the phosphorous at the rate of 0 kg/ha had the shortest plant height at all growth stages (11.56, 18.13 and 43.37 cm for 30, 45 and 60 DAT, respectively). This result indicates that phosphorous has tremendous effect on growth and development in tomato. This result is in agreement with that of Karim (1999) who reported that plant height increased with increased phosphorus rate up to 100 kg P/ha in tomato. Similar result was also reported by BINA (2009) in tomato that plant height increased with increasing phosphorus levels up to 120 kg P/ha.

The effect of different mulches on plant height at three growth stages was significant in tomato (Table 1). Results revealed that plant height was higher in mulch applied plot than control plot. This result indicate that application mulch enhance growth and development of tomato plants. The tallest plant was recorded in water hyacinth mulch at all growth stages (15.28, 27.05 and 54.48 cm for 30, 45 and 60 DAT, respectively) followed by rice straw (13.59, 25.42 and 51.86 cm for 30, 45 and 60 DAT, respectively). The plant height was higher in mulches than control because of might be moisture percentage was higher in those mulches plots compared to control plot (Biswas, 2009) which resulted increase nutrient availability and plants uptake more nutrients resulting higher growth and development. In contrast, the shortest plant (11.63, 21.93 and 47.44cm for 30, 45 and 60 DAT, respectively) was recorded in control plot where no mulch was used. In control plot, soil moisture was less than the mulches plots that causes lesser amount of nutrient availability. As a result, plant growth and development hampered (Biswas, 2009) and ultimately plant height was short. The plant height was higher in water hyacinth mulch than the other mulches as reported

Table 1. Effect of levels of phosphorus and mulches on plant height at different days after transplanting in tomato cv. Roma VF

Treatment	**Plant height (cm) at**		
Levels of phosphorus (kg/ha)	**30 DAT**	**45 DAT**	**60 DAT**
0 (P_0)	11.56	18.13	43.37
40 (P_{40})	12.39	22.34	49.60
80 (P_{80})	14.47	27.05	54.97
120 (P_{120})	15.10	30.99	56.14
Level of significance	**	**	**
LSD (0.05)	0.53	1.52	2.30
LSD (0.01)	0.69	1.98	3.09
Mulches	**30 DAT**	**45 DAT**	**60 DAT**
No mulch (M_0)	11.63	21.93	47.44
Water hyacinth (M_1)	15.28	27.05	54.48
Rice straw (M_2)	13.59	25.42	51.86
Banana leaves (M_3)	13.03	24.11	50.30
Level of significance	**	**	**
LSD (0.05)	0.61	1.76	2.65
LSD (0.01)	0.80	2.36	3.57

** indicate significant at 1% level of probability

P_0 = 0kg P/ha; P_{40} = 40kg P/ha; P_{80} = 80kg P/ha; P_{120} = 120kg P/ha

M_0 = No mulch; M_1 = Water hyacinth; M_2 = Rice straw; M_3 = Banana leaves.

by Singh *et al.,* (2006) in tomato which supported the present experimental result.

The variation in plant height at different DAT (30, 45 and 60 DAT) due to combined effect of phosphorus levels and mulches was significant (Table 2). The tallest plant was recorded in the treatment combination of 120 kg P/h with water hyacinth mulch at all growth stages (16.41, 33.62 and 60.92 cm for 30, 45 and 60 DAT, respectively) followed by 120 kg P/ha with rice straw mulch (15.58, 30.41 and 56.30 cm for 30, 45 and 60 DAT, respectively). The shortest plant was recorded in control plot (8.70, 14.34 and 40.26 cm for 30, 45 and 60 DAT, respectively) where no phosphorus and mulch was applied.

Number of leaves per plant

The effect of rate of phosphorus on the number of leaves per plant was significant and ranged from 36.93 to 52.47 (Table 3). Results revealed that the number of leaves per plant increased with increasing phosphorus level up to 80

Table 2. Combined effect of levels of phosphorus and different mulches on plant height at different days after transplanting in tomato cv. Roma VF

Treatment combination	Plant height (cm) at		
	30 DAT	**45 DAT**	**60 DAT**
P_0 M_0	8.70	14.34	40.26
P_0 M_1	13.60	20.33	45.40
P_0 M_2	12.40	19.19	45.11
P_0 M_3	11.57	18.67	42.73
P_{40} M_0	10.11	17.25	45.48
P_{40} M_1	14.93	25.58	53.34
P_{40} M_2	12.36	23.80	50.45
P_{40} M_3	12.19	22.74	49.13
P_{80} M_0	13.71	22.53	51.63
P_{80} M_1	16.20	30.38	58.26
P_{80} M_2	14.04	28.27	55.60
P_{80} M_3	13.94	27.05	54.39
P_{120} M_0	14.02	31.94	52.40
P_{120} M_1	16.41	33.62	60.92
P_{120} M_2	15.58	30.41	56.30
P_{120} M_3	14.42	28.00	54.95
Level of significance	**	**	*
LSD (0.05)	1.06	3.04	4.59
LSD (0.01)	1.43	4.09	6.18

*, ** indicate significant at 5% and 1% level of probability, respectively

P_0 = 0kg P/ha; P_{40} = 40kg P/ha; P_{80} = 80kg P/ha; P_{120} = 120kg P/ha

M_0 = No mulch; M_1 = Water hyacinth; M_2 = Rice straw; M_3 = Banana leaves.

kg P/ha and further increased the levels of P, leaf number was not significantly influenced (Table 3). The highest number of leaves per plant (52.47) was observed in 80 kg P/ ha (52.47) followed by 120 kg P/ha (52.20). In contrast, the control plot (P_0) produced the lowest number of leaves per plant (36.93). The lesser amount of phosphorus or no phosphorus application may not available for uptake by the plants in control plots and probably was not sufficient for

Table 3. Effect of levels phosphorus and mulches on leaf production and reproductive characters in tomato cv. Roma VF

Levels of Phosphorus (kg/ha)	Number of leaves per plant	Days to flowering	Number of flower clusters per plant	Number of flowers per cluster	Number of flowers per plant
0 (P_0)	36.93	34.05	16.44	3.87	74.16
40 (P_{40})	44.41	30.33	19.19	4.88	82.87
80 (P_{80})	52.47	24.85	21.73	5.87	96.34
120 (P_{120})	52.20	25.05	22.39	5.86	99.01
Level of sig.	**	**	**	**	**
LSD (0.05)	2.21	1.30	1.23	0.18	2.83
LSD (0.01)	2.87	1.69	1.60	0.23	3.68
Mulches					
No mulch (M_0)	38.41	30.54	17.51	4.45	72.96
Water hyacinth (M_1)	50.15	27.80	21.71	5.39	97.92
Rice straw (M_2)	50.00	28.11	20.60	5.35	95.89
Banana leaves (M_3)	47.46	27.80	19.93	5.29	85.60
Level of sig.	**	**	**	**	**
LSD (0.05)	2.56	1.50	1.42	0.21	3.26
LSD (0.01)	1.32	1.95	1.84	0.27	4.24

** indicate significant at 1% level of probability

P_0 = 0kg P/ha; P_{40} = 40kg P/ha; P_{80} = 80kg P/ha; P_{120} = 120kg P/ha

M_0 = No mulch; M_1 = Water hyacinth; M_2 = Rice straw; M_3 = Banana leaves.

normal plant growth and development and resulted in reduction of number of leaves per plant. This result is in full agreement with that of Gupta (2007) who stated that the number of leaves per plant increased with increasing phosphorous levels from 50 to 150 kg/ha in tomato.

Leaf number per plant varied significantly due to mulch application in tomato (Table 3). The highest number of leaves per plant (50.15) was recorded in water hyacinth mulch which was statistically similar to that of rice straw mulch (50.00). This result indicates that rice straw and water hyacinth mulches had similar effect on leaf production in tomato. In contrast, control plot where no mulch was used produced the lowest number of leaves per plant (38.41). Halim (2006) reported that use of mulches increased branch number in tomato than control plant which supported the present experimental result.

The combination between phosphorus and mulches had significant effect on leaf number in tomato (Table 4). The highest number of leaves per plant was recorded in the treatment combination of 80 kg P/ha with rice straw (57.30)

Table 4. Combined effect of levels of phosphorus and different mulches on leaf production and reproductive characters in tomato cv. Roma VF

Treatment combination	Number of leaves per plant	Days to flowering	Number of flower clusters per plant	Number of flowers per cluster	Number of flowers per plant
P_0 M_0	32.33	36.12	14.18	3.11	59.66
P_0 M_1	38.40	33.26	18.25	4.18	84.66
P_0 M_2	40.30	33.83	17.15	4.14	78.66
P_0 M_3	36.70	32.98	16.20	4.06	73.66
P_{40} M_0	37.30	32.67	17.05	4.50	70.23
P_{40} M_1	48.30	29.73	20.33	5.04	92.45
P_{40} M_2	46.70	29.92	20.21	5.01	88.31
P_{40} M_3	45.33	29.00	19.18	4.98	80.50
P_{80} M_0	42.50	27.04	19.21	5.09	77.95
P_{80} M_1	56.60	23.40	23.42	6.16	105.7
P_{80} M_2	57.30	24.03	22.46	6.10	109.7
P_{80} M_3	53.50	24.92	21.83	6.13	92.01
P_{120} M_0	41.50	26.35	19.62	5.11	84.00
P_{120} M_1	57.30	24.84	24.84	6.18	108.9
P_{120} M_2	55.70	24.69	22.60	6.17	106.9
P_{120} M_3	54.30	24.32	22.52	6.00	96.24
Level of sig.	*	*	*	*	*
LSD (0.05)	4.43	2.60	2.45	0.36	5.65
LSD (0.01)	5.96	3.50	3.30	0.48	7.60

* indicate significant at 5% level of probability

P_0 = 0kg P/ha; P_{40} = 40kg P/ha; P_{80} = 80kg P/ha; P_{120} = 120kg P/ha

M_0 = No mulch; M_1 = Water hyacinth; M_2 = Rice straw; M_3 = Banana leaves.

Table 6. Combined effect of levels phosphorus and different mulches on yield attributes and fruit yield in tomato cv. Roma VF

Treatment combination	Number of fruits per plant	Fruit length (cm)	Fruit diameter (cm)	Single fruit weight (g)	Fruit weight per plant (kg)
P_0 M_0	20.43	4.15	3.95	49.23	1.01
P_0 M_1	24.33	4.95	4.25	52.78	1.28
P_0 M_2	24.30	4.83	4.20	52.72	1.28
P_0 M_3	22.90	4.62	4.16	52.42	1.20
P_{40} M_0	24.21	5.65	4.00	55.67	1.35
P_{40} M_1	29.23	6.45	4.40	58.08	1.70
P_{40} M_2	28.05	6.29	4.35	57.21	1.60
P_{40} M_3	26.51	6.07	4.30	57.07	1.51
P_{80} M_0	27.64	6.12	4.00	58.52	1.62
P_{80} M_1	33.70	7.30	4.49	60.65	2.04
P_{80} M_2	31.50	7.22	4.43	60.02	1.89
P_{80} M_3	29.12	7.10	4.22	59.91	1.74
P_{120} M_0	28.70	6.22	4.10	59.07	1.70
P_{120} M_1	34.50	7.35	4.45	61.23	2.11
P_{120} M_2	32.07	7.20	4.45	60.05	1.96
P_{120} M_3	31.01	7.06	4.32	60.58	1.88
Level of sig.	*	*	NS	*	*
LSD (0.05)	3.37	0.29	0.54	3.14	0.32
LSD (0.01)	4.54	0.39	0.74	4.23	0.70

* indicate significant at 5% level of probability; NS = Not significant

P_0 = 0kg P/ha; P_{40} = 40kg P/ha; P_{80} = 80kg P/ha; P_{120} = 120kg P/ha

M_0 = No mulch; M_1 = Water hyacinth; M_2 = Rice straw; M_3 = Banana leaves.

and 120 kg P/ha with water hyacinth mulch (57.30). The lowest number of leaves per plant was observed in control plot (32.33).

Effect of levels of phosphorus, mulches and their combined effect on reproductive characters in tomato cv. Roma VF

Days to flowering

Different levels of phosphorus application on tomato cv. Roma VF have significant effect on days to flowering (Table 3). Results revealed that days to flowering was lesser in phosphorus applied plots than control plots (Table 3) which indicating application of phosphorus has effect on days required to flowering. The highest days required to flowering was recorded in control plot (34.05 days) and lower days required to maturity was recorded in 80 and 120 kg P/ha (24.85 and 25.05 days for 80 and 120 kg P/ha, respectively). The minimum days required in 80 and 120 kg P/ha might be due to the growth of the plants of these two treatments is quicker than control plant and reach quickly a physiological development and start flowering earlier than control plants (Gupta, 2007).

The effect of different mulches on days to flowering was significant in tomato (Table 3). The highest day to flowering was recorded in control plot (30.54 days) and the lowest day to flowering was recorded in water hyacinth and banana leaves mulches (27.80 days). Actually, within the mulch treatments there had no significant differences in days required to flowering (range 27.80-28.11 days). Use of mulch enhance flowering in tomato as reported by Biswas (2009) in tomato.

The combined effect of phosphorus levels and mulches on days to flowering was significant (Table 4). The highest days to flowering (36.12 days) was recorded in the treatment combination of 0 kg P/ha with no mulch and the lowest was recorded in 80 kg P/ha with water hyacinth mulch (23.40 days)

Number of flower clusters per plant

Phosphorus fertilization had significant effect on the number of flower cluster per plant (Table 3). Result revealed that the number of flower clusters per plant was greater in phosphorus applied plants than in control plants (Table 3). Result further revealed that the number of flower clusters per plant increased with increasing phosphorus levels till 120 kg P/ha. The higher number of flower cluster per plant was observed in 80 and 120 kg P/ha with being the highest in 120 kg P/ha (22.39). In contrast, the lowest number of flower clusters per plant was recorded in control plant (16.44) that was significantly different than the other treatments. Reduced number of flower cluster per plant under no phosphorus application might be due to less growth and development of the plant (BINA, 2009). These results are in conformity with those of BINA (2009) who reported that zero or lesser amount of P application had the lowest number of flower clusters per plant compared to higher doses in tomato.

Flower cluster number per plant varied significantly due to mulch application in tomato (Table 3). Results revealed that flower cluster number was greater in mulch plant than in control. The highest number of flower cluster per plant was recorded in water hyacinth mulch (21.71) followed by rice straw mulch (20.60) with same statistical rank. In contrast, control plot where no mulch was used produced the lowest number of flower cluster per plant (17.51). Halim (2006) reported that use of mulches increased flower cluster number in tomato than control plant which supported the present experimental result.

The combined effect between phosphorus levels and mulches on flower cluster number per plant was significant (Table 4). The higher number of flower cluster per plant was recorded in water hyacinth mulch with 80 and 120 kg P/ha with being the highest in 120 kg P/ha with water hyacinth mulch (24.84). The lowest number of flower cluster was observed in control plot (14.18).

Number of flowers per cluster

Phosphorus fertilization had significant effect on the number of flowers per cluster (Table 3). Result revealed that the number of flowers per cluster was higher in phosphorus applied plants than in control plants (Table 3). Result further revealed that the number of flowers per cluster increased with increasing phosphorus levels till 80 kg P/ha. The higher number of flowers per cluster was observed in 80 and 120 kg P/ha with being the highest in 80 kg P/ha (5.87). The lowest number of flowers per cluster was recorded in control plant (3.87 that was significantly different than the other treatments. Reduced number of flowers per cluster under no phosphorus application might be due to lower growth and development for less P-uptake. These results are in conformity with those of Sharma and Mann (2002) who reported that zero or lesser amount of P application had the lowest number of flowers per cluster compared to higher doses in tomato.

Flower number per cluster varied significantly due to mulch application in tomato (Table 3). The highest number of flowers per cluster (5.39) was recorded in water hyacinth mulch which was statistically similar to that of rice straw (5.35) and banana leaves mulch (5.29). This result indicates that water hyacinth; rice straw and banana leaves mulches had similar effect on flower number per cluster. In contrast, control plot where no mulch was used produced the lowest number of flowers per cluster (4.45). Ali (2002) reported that use of mulches increased flower number per cluster in tomato than control plant which supported the present experimental result.

The combined effect between phosphorus level and mulches had significant effect on flower number per cluster in tomato (Table 4). The highest number of flowers per cluster was recorded in the treatment combination of 120 kg P/ha with water hyacinth (6.18) followed by 120 kg P/ha with rice straw mulch (6.17). The lowest number of flowers per cluster was observed in control plot (3.11).

Number of flowers per plant

The effect of phosphorus on flower number per plant was significant (Table 3). Result revealed that the number of filled flowers per plant increased with increasing phosphorus levels. The highest number of flowers per plant was observed in 120 kg P/ha (99.01) followed by 80 kg P/ha (96.34) with same statistical rank. In contrast, the lowest number of flowers per plant was recorded in control plant (74.16). Ummed *et al*., (2003) reported that application of phosphorus increased flower production in tomato that supported the present experimental result.

Flower number per plant varied significantly due to mulch application in tomato (Table 3). Result revealed that fruit number was greater in mulch plant than control plant. This result indicates that use of mulch enhance flower production in tomato. The highest number of flowers per plant was recorded in water hyacinth mulch (97.92) which was non-significant different to rice straw mulch (95.89). The flower number was higher in water hyacinth and rice straw mulches due to production of higher flower clusters per plant. In contrast, control plant produced the lowest number of flowers per plant (72.96) due to fewer flower cluster per plant. Gutal *et al*., (2002) reported that use of mulches increased fruit number in tomato than control plant which supported the present experimental result.

The combined effect of phosphorus level and mulches had significant effect on flower number in tomato (Table 4). The highest number of flowers per plant was recorded in the treatment combination of 80 kg P/ha with rice straw (109.7). The lowest number of flowers per plant was observed in control plant (59.66).

Effect of levels of phosphorus, mulches and their combined effect on yield attributes and fruit yield in tomato cv. Roma VF

Number of fruits per plant

The effect of phosphorus levels on the number of fruits per plant was significant and ranged from 22.99 to 31.57 (Table 5). Results revealed that the number of fruits per plant increased with increasing phosphorus level but significantly increased up to 80 kg P/ha (Table 5). The highest number of fruits per plant (31.57) was observed in 120 kg P/ha, (52.47) followed by 80 kg P/ha (30.49) with same statistical rank. This result indicates that 80 kg P/ha is sufficient for getting maximum fruits per plant in tomato. In contrast, the control plot (P_0) produced the lowest number of fruits per plant (22.99). The lesser amount of phosphorus or no phosphorus application may not available for uptake by the plants in control plots and probably was not sufficient for normal plant growth and development and resulted in reduction of number of fruits per plant. This result is in full agreement with that of Gupta (2007) who stated that the number of fruits per plant increased with increasing phosphorous levels from 50 to 150 kg/ha in tomato.

Fruit number per plant varied significantly due to mulch application in tomato (Table 5). The highest number of fruits per plant (28.98) was recorded in water hyacinth mulch which was statistically similar to that of rice straw mulch (28.98). This result indicates that rice straw and water hyacinth mulches had similar effect on fruit production in tomato. In contrast, control plot where no mulch was used, produced the lowest number of fruits per plant (25.24) due to fewer flower cluster per plant. Halim (2006) reported that use of mulches increased fruit number in tomato than control plant which supported the present experimental result. The combined effect of phosphorus level and mulches had significant effect on fruit number in tomato (Table 6). The highest number of fruits per plant was recorded in the treatment combination of 120 kg P/ha with water hyacinth mulch (34.50) and followed by 80 kg P/ha with water hyacinth mulch (33.70) with same statistical rank. The lowest number of fruits per plant was observed in control plot (20.43) where on P and mulch used.

Fruit length

Different levels of phosphorus application had significant effect on fruit length (Table 5). Results revealed that fruit length was greater in phosphorus applied plots than control plots (Table 5) indicating application of phosphorus had effect on fruit length. Results further revealed that fruit length increased with increasing phosphorus levels. The highest fruit length (6.95 cm) was recorded in 120 kg P/ha that was non significant different to 80 kg P/ha (6.93 cm). The lowest fruit length was recorded in control plant (4.64 cm). Slaton *et al.,* (2002) observed that application of phosphorous fertilizer increased fruit length of tomato that supported the present experimental result.

The effect of different mulches on fruit length was significant of tomato (Table 5). Result showed that fruit length was higher in mulch plots than control plots. The highest fruit length was recorded in water hyacinth mulch (6.51cm) and the lowest was recorded in control (5.53 cm). This result agrees with finding of Halim (2006) in tomato who reported that mulches had significant effect on fruit length in tomato. The combined effect of phosphorus level and mulches had significant effect on fruit length in tomato (Table 6). The higher fruit length was recorded in water hyacinth mulch with 80 or 120 kg P/ha. The lowest fruit length was observed in control plant (4.15 cm).

Fruit diameter

The effect of different phosphorus levels on fruit diameter was significant in tomato (Table 5). Results showed that fruit diameter increased with increasing phosphorus levels up to 120 kg/ha. The highest fruit diameter was recorded in 120 kg P/ha (4.33 cm) followed by 80 kg P/ha (4.29 cm)

Table 7. Effect of levels of phosphorus and mulches on yield attributes and fruit yield in tomato cv. Roma VF

Phosphorus levels (kg/ha)	**Number of fruits per plant**	**Fruit length (cm)**	**Fruit diameter (cm)**	**Single fruit weight (g)**	**Fruit weight per plant (kg)**
0 (P_0)	22.99	4.64	4.14	51.78	1.19
40 (P_{40})	27.00	6.11	4.26	57.00	1.54
80 (P_{80})	30.49	6.93	4.29	59.77	1.82
120 (P_{120})	31.57	6.95	4.33	60.23	1.91
Level of sig.	**	**	*	**	**
LSD (0.05)	1.68	0.14	0.16	1.57	0.15
LSD (0.01)	2.18	0.19	0.36	1.96	1.14
Mulches					
No mulch (M_0)	25.24	5.53	4.01	55.62	1.42
Water hyacinth (M_1)	30.44	6.51	4.40	58.18	1.78
Rice straw (M_2)	28.98	6.38	4.36	57.50	1.68
Banana leaves (M_3)	27.38	6.21	4.25	57.49	1.58
Level of sig.	**	**	*	*	**
LSD (0.05)	1.94	0.17	0.37	1.81	0.18
LSD (0.01)	2.52	0.22	0.48	2.46	0.22

*, ** indicate significant at 5% and 1% level of probability, respectively

P_0 = 0kg P/ha; P_{40} = 40kg P/ha; P_{80} = 80kg P/ha; P_{120} = 120kg P/ha

M_0 = No mulch; M_1 = Water hyacinth; M_2 = Rice straw; M_3 = Banana leaves.

and 40 kg P/ha (4.26 cm) with same statistical rank. In contrast, the phosphorous at the rate of 0 kg/ha had the lowest fruit diameter (4.14 cm). This result indicates that phosphorous has tremendous effect on growth and development of fruit in tomato. This result is in agreement with that of Karim (1999) who reported that plant fruit diameter increased with increased phosphorus rate up to 100 kg P/ha in tomato. Similar result was also reported by BINA (2009) in tomato that fruit diameter increased with increasing phosphorus levels up to 120 kg P/ha.

The effect of different mulches on fruit diameter was significant in tomato (Table 5). Results revealed that fruit diameter was higher in mulch applied plot than control plot. This result indicate that application mulch enhance growth and development of tomato fruits. The thickest fruit was recorded in water hyacinth mulch (4.40cm) followed by rice straw (4.36 cm). In contrast, the thinner fruit was observed in control plant (4.01 cm). In control plot, soil moisture was less than the other mulches that causes lesser amount of nutrient availability. As a result, fruit growth and

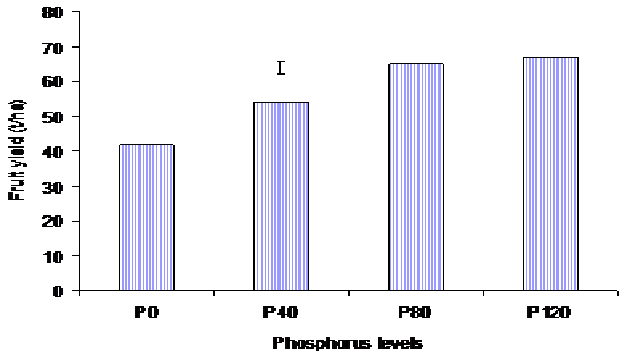

Figure 1. Effect of levels of phosphorus on fruit yield in tomato cv. Roma VF vertical bar represents LSD at the 5% level of probability (P_0 = 0kg P/ha, P_{40} = 40kg P/ha, P_{80} = 80kg P/ha; P_{120} = 120kg P/ha.)

development hampered (Biswas, 2009) and ultimately shorter fruit developed in tomato. The fruit diameter was higher in water hyacinth mulch than the other mulches as reported by Singh *et al.,* (2006) in tomato which supported the present experimental result. The variation in fruit diameter due to combined effect of phosphorus levels and mulches was non-significant (Table 6). However, the apparent thickest fruit was recorded in the treatment combination of 80 kg P/ha with water hyacinth mulch (4.49 cm). The apparent thinner fruits were recorded in control plot (3.95 cm) where no phosphorus and mulch was applied.

Single fruit weight

The effect of different levels of phosphorus on single fruit weight was statistically significant at P ≤ 0.01 (Table 5). Result revealed that single fruit weight increased with increasing phosphorus levels. The highest single fruit weight was observed in 120 kg P/ha (60.23 g) which was statistically similar to 80 kg P/ha (59.77 g). In contrast, the lowest single fruit weight was recorded in control plant (51.78 g). Reduction in single fruit weight of low phosphorous rate might be due to unavailable assimilate translocated to the fruits. Similar result was also reported by many workers (Zaman *et al*., 1997; Slaton *et al*., 2002; Ummed *et al*., 2003; Tamgale *et al.,* 2006; Babu and Seshaiah, 2006). They observed that single fruit weight decreased under low phosphorus levels in tomato. Single fruit weight was significantly affected by different mulches in tomato (Table 5). Result revealed that single fruit weight was greater in mulch plant than control but within the mulch treatments, there had no significant different in single fruit weight. This result is consistent with result of Saha (2003) who reported that single fruit weight was higher mulch plants than control plants.

The combined effect between phosphorus levels and mulching on single fruit weight was significant (Table 6). The individual fruit weight ranged 49.23-61.23 g among the treatment combinations. The treatment combination of 120 kg P/ha with water hyacinth showed the highest single fruit weight (61.23 g) and the lowest was recorded in the treatment combination of 0 kg P/ha with no mulch (49.23 g).

Fruit yield

Fruit yield per plant and per hectare was significantly influenced by different levels of phosphorus application (Table 5 and Fig. 1). Result showed that fruit yield was

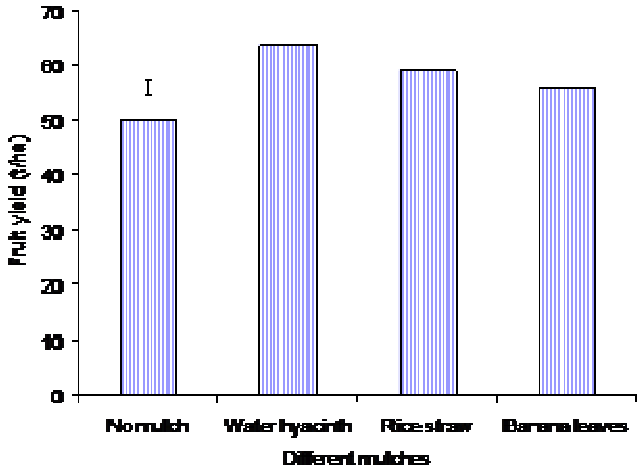

Figure 2. Effect of different mulches on fruit yield in tomato cv. Roma VF Vertical bar represents LSD at the 5% level of probability (M_0 = No mulch, M_1 = Water hyacinth, M_2 = Straw, M_3 = Banana leaf)

higher in phosphorus applied plot than in control plot where no phosphorus was applied indicating application of phosphorus had effect on fruit yield (Table 5). Result revealed that fruit yield increased with increasing amount of phosphorus application but the increment was significant over control plant upto 80 kg P/ha and further increased P, fruit yield was not significantly increased over 80 kg P/ha. This result indicates that 80 kg P/ha is the optimum for getting higher yield in tomato. The highest fruit yields both per plant and per hectare were observed in 120 kg P/ha (1.91 kg/plant and 66.2 t /ha) followed by 80 kg P/ha (1.82 kg per plant and 63.4 t/ha) with same statistical rank. The fruit yield was the higher in 120 and 80 kg P/ha applied plants because of production of higher number of flower cluster and fruits per plant compared to other treatments (Table 3 & 5). On the contrary, control plot (P_0) produced the lowest fruit yield (1.19 kg per plant and 42.5 t/ha) due to production of lesser flower cluster and fruits per plant. Fruit yield variations in tomato due to phosphorus application was also observed by many researchers (Karim, 1999; Ummed *et al*., 2003; Tamgale *et al*., 2006; Babu and Seshaiah, 2006).

Mulches had significant effect on fruit yield in tomato (Table 5 and Fig. 2). Result showed that fruit yield was greater in mulch plot than control plot. The highest fruit yield was recorded in water hyacinth mulch (1.78 kg per plant and 62.39 t/ha) followed by rice straw mulch (1.68 kg per plant and 58.89 t/h). The fruit yield was higher in water hyacinth mulch because of production of higher number of fruits per plant. In contrast, the lowest fruit yield was recorded in control plant (1.42 kg per plant and 49.70 t/ha). Similar results were reported by Biswas (2009) in tomato who observed that fruit yield increased in mulched plots with being the highest in water hyacinth mulch.

The combined effect of phosphorus levels and mulching on fruit yield both per plant and per hectare was significant (Table 6 and Fig. 3). The treatment combination of 80 and 120 kg P/ha with water hyacinth showed the higher fruit yield (averaged 2.08 kg per plant and 72.63 t/ha) and the lowest was recorded in the treatment combination of 0 kg

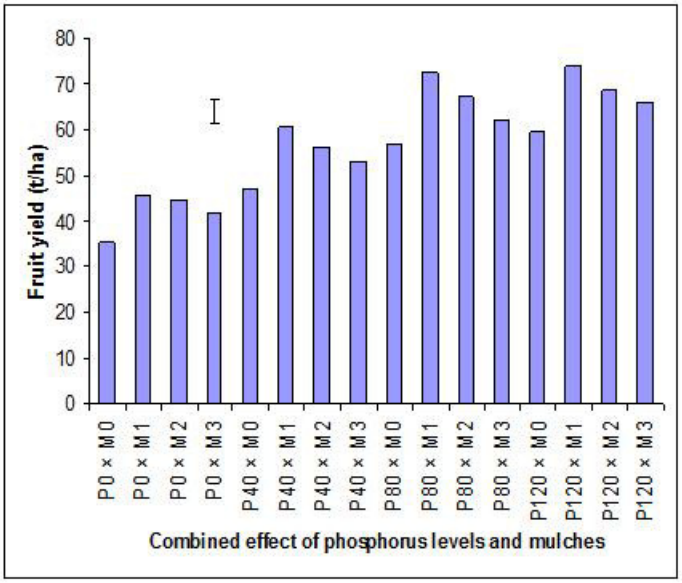

Figure 3. Combined effect of levels of phosphorus and different mulches on fruit yield in tomato cv. Roma VF. (P0 = 0kg P/ha, P40 = 40kg P/ha, P80 = 80kg P/ha; P120 = 120kg P/ha; M_0 = No mulch, M_1 = Water hyacinth, M_2 = Straw, M_3 = Banana leaf)

P/ha with no mulch (1.01 kg per plant and 35.35 t/ha). This result indicates that 80 kg P/ha along with water hyacinth is the best for maximizing tomato fruit yield.

CONCLUSION

In this study, it may be concluded that tomato growth and yield were affected by different levels of phosphorus application and the highest fruit yield (73.85 t/ha) was found from 120 kg P/ha which statistically similar to the highest 80 kg P/ha of suggesting that application of 80 kg P/ha to be economic for tomato cultivation. Mulches had significant positive influence on growth and yield of tomato over control; and among the mulches, water hyacinth had remarkable superiority for plant growth and yield (73.85 kg/ha) over control mulch (35.35 kg/ha) which resulting the highest fruit yield in tomato. So, we may use water hyacinth mulch for increased tomato fruit yield during winter season; and the treatment combination of 80 kg P/ha with water hyacinth mulch is suitable for maximizing fruit yield of tomato cv. Roma VF.

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