



Integrated nutrient management and mulching for higher productivity of spur type apple (*Malus domestica*) cultivars

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ABSTRACT

Integrated nutrient combination comprising NPK sources from organic manures (FYM and vermicompost) and inorganic sources along with mulching (leaf mould and black polyethylene) were applied on apple (*Malus domestica* Borkh) cv. Starkrimson planted on high density system. The objective was to supplement NPK requirement by applying sufficient quantity of organic manures, thereby, minimizing the inorganic fertilizer requirement. Better result was obtained in treatment comprising leaf mould mulch and integrated nutrients: 50 kg/tree FYM + 10 kg/tree vermicompost + 50 g/tree N + 75 g/tree P₂O₅ + 250 g/tree K₂O in 5th year; 60 kg/tree FYM + 13 kg/tree vermicompost + 30 g/tree N + 80 g/tree P₂O₅ + 225 g/tree K₂O in 6th year; 70 kg/tree FYM + 16 kg/tree vermicompost + 10 g/tree N + 85 g/tree P₂O₅ + 250 g/tree K₂O in 7th year and 70 kg/tree FYM + 19 kg/tree vermicompost + 165 g/tree N + 178 g/tree P₂O₅ + 548 g/tree K₂O in both 8th and 9th year. In the 8th and 9th year, this treatment resulted comparatively higher fruit yield (31.8 and 30.6 kg/tree, respectively) and productivity (50.8 and 53.3 MT/ha, respectively) with fruit weight 200.4 and 202.4 g and diameter 8.4 and 8.2 cm, respectively. Whereas, in recommended dose, in 8th and 9th year, 27.6 and 25.6 kg/tree yield and 44.2 and 40.9 MT/ha productivity were recorded, respectively. Reduction of FYM quantity by 50% and increasing the vermicompost dose also supplemented considerable amount of NPK requirement from inorganic sources and resulted better plant growth and yield.

Key words: Apple productivity, Integrated nutrient management, Mulching, Starkrimson, Vermicompost

Apple (*Malus domestica* Borkh) under higher density planting system has greater advantage in terms of maximum number of plants per unit area, cultivar novelty, efficient canopy and orchard management and consequently higher productivity of better quality fruits. High density concept of orcharding was given thrust in India for wide adoption of improved apple cultivars specifically spurs types on clonal rootstocks. Productivity of apple in India is very low (8 MT/ha) in comparison to other major apple producing countries namely China USA (30.9 MT/ha), New Zealand (50.6 MT/ha) and Austria (77.9 MT/ha). Though, estimated apple production in India is 2 497.7 thousand MT over an area of 313 thousand ha (FAO 2014 and NHB 2015), majority of the old plantations are under traditional density comprising old cultivars. High density apple orcharding was well adopted in apple producing states like J & K and Himachal

Pradesh. However, large scale distribution and adoption of superior apple cultivars especially spur types on clonal rootstocks in Uttarakhand over the last 7-8 years was viewed as a positive development in area expansion and replacing senile orchards as well as the old varieties such as Fenny, Early Shunburry, Buckingham and Rhymer etc. Under such scenario, orchard nutrition management for the high density plantations of spur type cultivars based on farmer's friendly integrated nutrient combinations will be very much beneficial. An integrated nutritional management programme in principle is based on judicious and balanced supply of need based nutrient from organic and inorganic sources at appropriate proportions and at specified time schedule depending upon the age of the tree. Mulching plays a significant role in conserving soil moisture and in controlling weed growth besides many other advantages. Organic manures in sufficient quantities not only supplement NPK requirement from inorganic fertilizer sources, but also reduce the total quantity of inorganic fertilizers required as per fertilizer schedule. Integrated application of organic manures and inorganic fertilizers enhances overall performance of apple trees in terms of plant growth, yield and fruit quality (Verma and Chauhan 2013) and organic mulches also facilitates better availability of nutrients like N, P, K, Ca,

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Table 1 Treatment combination of integrated nutrients and mulching for apple cv Starkrimson from 5th to 9th years

Treatment	Mulching	5th year				6th year				7th year				8th and 9th year							
		Organic manures (kg/tree)		Inorganic fertilizer(g/tree)		Organic manures (kg/tree)		Inorganic fertilizer(g/tree)		Organic manures (kg/tree)		Inorganic fertilizer(g/tree)		Organic manures (kg/tree)		Inorganic fertilizer(g/tree)					
		FYM	Vermi-compost	N	P ₂ O ₅	K ₂ O	FYM	Vermi-compost	N	P ₂ O ₅	K ₂ O	FYM	Vermi-compost	N	P ₂ O ₅	K ₂ O	FYM	Vermi-compost	N	P ₂ O ₅	K ₂ O
T ₁	Black polyethylene	50	0	350	175	350	60	0	420	210	420	70	0	490	245	490	70	0	735	368	833
T ₂	Leaf mould	50	0	350	175	350	60	0	420	210	420	70	0	490	245	490	70	0	735	368	833
T ₃	No mulch	50	0	350	175	350	60	0	420	210	420	70	0	490	245	490	70	0	735	368	833
T ₄	Black polyethylene	50	5	200	125	325	60	8	180	130	300	70	11	160	135	325	70	14	315	228	623
T ₅	Leaf mould	50	5	200	125	325	60	8	180	130	300	70	11	160	135	325	70	14	315	228	623
T ₆	No mulch	50	5	200	125	325	60	8	180	130	300	70	11	160	135	325	70	14	315	228	623
T ₇	Black polyethylene	50	10	50	75	250	60	13	30	80	225	70	16	10	85	250	70	19	165	178	548
T ₈	Leaf mould	50	10	50	75	250	60	13	30	80	225	70	16	10	85	250	70	19	165	178	548
T ₉	No mulch	50	10	50	75	250	60	13	30	80	225	70	16	10	85	250	70	19	165	178	548
T ₁₀	Black polyethylene	25	15	100	125	300	30	18	120	150	300	35	21	140	175	350	35	24	295	268	648
T ₁₁	Leaf mould	25	15	100	125	300	30	18	120	150	300	35	21	140	175	350	35	24	295	268	648
T ₁₂	No mulch	25	15	100	125	300	30	18	120	150	300	35	21	140	175	350	35	24	295	268	648

Mg and B for enhancing fruit yield and quality without any negative effect (Merwe 2012). Considering all these, the present study was carried out with the objectives to examine the effect of different mulching and integrated nutrient management on the performance of vegetative growth, fruit yield and quality of spur type apple cv. Starkrimson under high density plantation system.

MATERIALS AND METHODS

The experiment was conducted in experimental apple high density orchard of Central Institute of Temperate Horticulture, Regional Station, Mukteshwar, situated at an altitude of 7 000 ft. above msl, during the years 2006 to 2011. The experiment was laid out on 5th year old bearing apple trees of spur type cv. Starkrimson on rootstock MM 106 planted in high density system with 2.5 × 2.5 m spacing in terraces and conducted for successive 5 bearing years, i.e. up to 9th bearing year of the apple trees. Pollinizer was Golden Spur Delicious. An integrated nutrient schedule comprising organic manures and inorganic fertilizers was formulated (Table 1) on the basis of annual requirement of nutrient elements for apple plants (Anonymous 2003) starting from 5 to 9th bearing years. Total elemental N, P and K nutrient requirement as estimated were 750, 900, 1 050 and 1 295 g/tree N, 375, 450, 525 and 648 g/tree P₂O₅ and 650, 780, 910 and 1 183 g/tree K₂O in 5th, 6th, 7th and 8/9th years, respectively. Farmyard manure (N: 0.8%, P₂O₅: 0.5% and K₂O: 0.5%) and vermicompost (N: 3.0%, P₂O₅: 1.0% and K₂O: 1.5%) as organic sources along with Urea, DAP and MOP as inorganic fertilizers were combined in different quantities to meet the total requirement of N P and K elements as per the annual requirement of apple trees (Table 1). Full as well as half dose of farm yard manure was applied in combination of different doses of vermicompost and inorganic fertilizers in different years as mentioned in Table 1. Organic manures were applied during the last week of December along with full dose of P₂O₅ and K₂O. Half dose of N was applied 15 days before expected flower bud burst and rest half after 15 day of fruit set (Anonymous 2003, Awasthi and Chadha 2005). Mulches were applied covering the tree basin soil during the end of monsoon, i.e. last week of September, which was removed during the onset of next monsoon. One set of trees were kept as control with only nutrient treatment in different combinations (Table 1), but without any mulch treatment (T₃, T₆, T₉ and T₁₂). On the other hand, treatment combinations namely T₁, T₂ and

T₃ received recommended dose of nutrients from FYM and inorganic sources without any vermicompost. Observations were recorded on plant growth, bloom and yield parameters (Westwood 1993) such as tree height, trunk girth, annual shoot growth, bloom period, bloom density (nos. of flower cluster/cm² branch cross sectional area), fruit set {(number of fruits set/number of flower clusters)×100}, fruit weight (g), fruit length and diameter (cm), TSS (%), acidity (%), yield (Kg/tree) and productivity (MT/ha). Pre-experimental soil nutrient status of the orchard was pH 5.6, EC 0.8 dS/m¹, OC 2.1%, 160 ppm N, 50 ppm P and 130 ppm K. The experiment was laid out in Randomized Block Design (RBD) comprising of 12 treatments and 3 replications.

RESULTS AND DISCUSSION

Data interpretation on blooming behavior over the years (Table 2) indicated that duration of total bloom and full bloom (75-80% flowers open stage) gradually increased from 13.4 to 20.1 days and 4.8 to 6.3 days, respectively, irrespective of treatment combination from 5 to 9th year. Whereas, treatments combinations T₄ (22 and 6.4 days), T₈ (22 and 6.2 days), T₁₀ (21.8 and 5.8), T₅ (21.4 and 5.6 days) and T₁₁ (21.2 and 6.8 days) showed comparatively extended period of total bloom and full bloom duration, respectively, under INM and mulch irrespective of plant age as also evident from the overall mean values (Table 2). In the 5th year, the range of total bloom duration was 8 to 17 days. However, in the successive years (6 to 9th year) it was observed that duration of total bloom period increased and was in the range of 14 days to 25 days with mean values of 19.3, 21.0, 20.8 and 20.1 days in 6th, 7th, 8th and 9th year, respectively. On the other hand, bloom density was only 10.6 in the 5th year, which increased to 13.7, 14.7, 17.1, and 17.6, respectively in the successive years under study. Leaf mould mulching in combination of increased level of NPK from organic sources and reduced level from inorganic sources resulted in the highest bloom density in T₈ (17.9), followed by treatment T₁₁ (17.2) and T₅ (17.0). Black polyethylene mulching also resulted in higher bloom density with integrated nutrient combination in treatments T₇ (16.8) and T₁₀ (16.1). Significant increment in bloom density as well as full bloom duration is the positive effect of incorporation of sufficient quantity of organic manures and mulch cover. Supply of major part of elemental nutrients from organic sources as per the estimated dose resulted in increased spur density as well as longer period of bloom especially in 8 and 9th year of apple cv. Starkrimson under HDP in the present study.

Integrated nutrient combination comprising much of NPK supplemented from organic sources has resulted in better plant growth (Table 3) in terms of mean plant height 2.7 m in T₈ and 2.6 m in both the treatments T₇ and T₅. Maximum trunk diameter 6.7 cm was also recorded in treatments T₅, T₇, T₈ and T₁₁, either with leaf mould or black polyethylene mulch. However, plant height and diameter was comparatively lesser in trees which did not receive mulching. All the plants, irrespective of treatment

Table 2 Blooming behavior of cv. Starkrimson under integrated nutrient and mulching management

Treatment	Total bloom duration (days)					Total full bloom duration					Bloom density						
	5th year	6th year	7th year	8th year	9th year	5th year	6th year	7th year	8th year	9th year	5th year	6th year	7th year	8th year	9th year	Mean	CV(%)
T ₁	12	23	23	22	23	5	4	5	6	6	10.3	14.3	15.3	17.3	16.4	14.7	18.5
T ₂	13	22	22	21	21	5	5	7	7	7	11.7	14.7	16.7	18.7	17.3	15.8	17.2
T ₃	8	14	17	14	14	4	3	5	5	4	7.5	11.5	9.5	12.5	12.5	10.7	20.3
T ₄	17	23	24	23	23	6	6	6	6	8	10.8	14.6	15.6	19.6	18.6	15.8	22.0
T ₅	15	20	25	24	23	5	4	6	6	7	11.9	15.1	17.8	19.8	20.3	17.0	20.6
T ₆	10	14	17	16	16	3	4	5	5	7	8.5	11.5	10.5	13.5	12.9	11.4	17.5
T ₇	15	20	23	24	22	6	5	7	6	7	12.5	14.9	16.2	19.2	21.4	16.8	20.9
T ₈	17	23	24	25	21	5	6	6	5	7	12.9	15.4	17.4	21.4	22.2	17.9	22.1
T ₉	12	15	17	16	15	5	4	5	4	5	8.9	11.9	12.7	12.7	13.3	11.9	14.7
T ₁₀	15	21	24	25	24	5	5	7	6	6	11.2	14.4	16.6	18.6	19.8	16.1	21.3
T ₁₁	17	22	22	23	22	5	6	7	7	6	12.6	14.7	17.8	19.8	21.3	17.2	20.8
T ₁₂	10	15	14	17	17	4	3	6	4	5	8.5	11.6	10.6	12.6	14.8	11.6	20.1
Mean	13.4	19.3	21.0	20.8	20.1	4.8	4.6	6.0	5.6	6.3	10.6	13.7	14.7	17.1	17.6	14.7	19.1
CD (P=0.05)	1.6	1.8	2.0	1.8	1.8	0.8	1.1	0.8	0.8	0.8	0.3	0	0.4	0.1	0.12	1.2	1.2
CV(%)	23	19	18	19	18	20.9	23.6	14.2	17.8	18.2	36.3	33.4	35.1	28.0	26.0	29.5	29.5

Table 3 Tree growth parameters of cv. Starkirmson under Integrated nutrient and mulching management

Treatment	Plant height (m)					Trunk dia. (cm)					Annual shoot growth (cm)										
	5th year	6th year	7th year	8th year	9th year	Mean	CV (%)	5th year	6th year	7th year	8th year	9th year	Mean	CV (%)	5th year	6th year	7th year	8th year	9th year	Mean	CV (%)
T ₁	1.8	2.1	2.4	3.0	3.2	2.5	23.7	5.4	6.3	6.5	6.9	7.0	6.4	9.9	55.3	60.3	66.3	69.4	70.8	64.4	10.1
T ₂	1.9	1.9	2.4	2.7	2.9	2.4	20.1	5.3	6.1	6.6	6.7	6.8	6.3	9.8	53.0	63.0	66.4	68.4	71.4	64.4	11.0
T ₃	1.6	1.8	2.3	2.6	2.8	2.2	22.2	5.0	6	6.2	6.4	6.5	6.0	10.0	50.5	55.5	60.5	64.6	68.6	59.9	12.0
T ₄	1.7	2.3	2.5	2.9	3.2	2.5	22.9	6.0	6.5	6.7	6.9	7.1	6.6	6.4	65.0	72.4	74.4	78.4	80.3	74.1	8.1
T ₅	2.0	2.3	2.6	3.0	3.1	2.6	17.8	5.8	6.7	6.9	7.0	7.1	6.7	7.8	63.4	73.4	77.4	83.5	86.7	76.9	11.9
T ₆	1.9	1.9	2.1	2.8	2.9	2.3	21.0	5.1	5.7	5.9	6.6	6.7	6.0	11.1	55.5	68.5	69.5	71.3	78.2	68.6	12.0
T ₇	2.0	2.6	2.7	3.0	3.2	2.6	18.0	6.1	6.6	6.7	7.1	7.2	6.7	6.5	68.3	70.3	69.5	79.5	82.5	74.0	8.8
T ₈	1.7	2.4	2.8	2.9	3.0	2.7	20.2	6.3	6.5	6.7	6.7	7.4	6.7	6.2	68.9	73.2	79.0	78.8	85.7	77.1	8.3
T ₉	1.8	1.8	2.2	2.6	2.7	2.1	18.1	5.2	6	6.3	6.5	6.7	6.1	9.5	61.2	65.5	68.5	68.5	67.2	66.2	4.6
T ₁₀	1.8	1.9	2.7	2.9	3.0	2.5	22.2	5.4	6.4	6.6	7.3	7.5	6.6	12.5	63.6	70.2	72.3	78.3	80.1	72.9	9.1
T ₁₁	1.8	2.5	2.6	2.7	2.8	2.4	16.0	5.7	6.6	6.8	7.2	7.4	6.7	9.8	69.3	72.5	70.5	80.5	82.7	75.1	8.1
T ₁₂	1.7	1.9	2.3	2.5	2.6	2.2	17.6	5.3	5.5	5.8	6.8	6.9	6.1	12.3	56.0	60.8	63.8	67.8	68.1	63.3	8.0
Mean	1.8	2.1	2.5	2.8	3.0	2.4	19.4	5.6	6.2	6.5	6.8	7.0	6.1	9.0	60.8	67.1	69.8	74.1	76.9	68.6	9.0
CD (P=0.05)	0.02	0.1	0.1	0.03	0.1	0.2		0.1	0.2	0.1	0.3	0.2	0.3		1.0	1.3	1.3	1.2	1.4	1.7	
CV(%)	6.9	12.3	8.9	6.3	6.9	6.5		7.6	6.1	5.4	4.1	4.5	4.8		10.8	8.9	7.7	8.5	9.4	8.5	

Table 4 Fruit physical parameters of cv. Starkirmson under Integrated nutrient and mulching management

Treatment	Fruit weight (g)					Fruit length (cm)					Fruit dia. (cm)										
	5th year	6th year	7th year	8th year	9th year	Mean	CV (%)	5th year	6th year	7th year	8th year	9th year	Mean	CV (%)	5th year	6th year	7th year	8th year	9th year	Mean	CV (%)
T ₁	168	190.0	193.0	196.3	194.8	188.4	6.2	5.5	7.5	7.4	7.5	7.3	7.0	12.3	6.3	7.8	7.5	7.7	7.5	7.4	8.2
T ₂	165	192.0	194.0	197.5	196.2	188.9	7.2	5.7	7.3	7.1	7.3	7.4	7.0	10.2	6.5	7.7	7.4	7.5	7.7	7.4	6.8
T ₃	164	170.0	175.0	181.3	178.6	173.8	4.0	5.8	6.6	6.2	6.7	6.6	6.4	5.9	6.3	7.0	6.9	7.0	7.1	6.9	4.7
T ₄	170	185.0	188.0	198.1	196.1	187.4	6.0	6.1	7.4	7.6	7.7	7.6	7.3	9.2	6.8	7.8	7.9	8.1	8.0	7.7	6.8
T ₅	173	198.2	197.5	197.5	199.4	193.1	5.8	6.3	7.9	7.8	7.9	7.8	7.5	9.2	7.0	8.3	8.1	8.3	8.1	8.0	6.9
T ₆	168	174.5	176.2	186.2	179.6	176.9	3.8	6.0	6.8	6.9	7.1	6.5	6.7	6.4	6.5	7.3	7.2	7.6	7.0	7.1	5.7
T ₇	171	198.3	198.6	200.6	199.7	193.6	6.6	6.8	7.8	7.7	7.7	7.5	7.5	2.0	7.9	8.3	8.2	8.2	8.2	8.2	1.9
T ₈	188	197.0	200.4	200.4	202.4	197.6	2.9	7.6	7.7	7.9	7.9	7.6	7.7	5.4	8.1	8.2	8.4	8.4	8.2	8.3	1.6
T ₉	155	174.0	179	186.0	187.0	176.2	7.4	6.3	6.5	6.6	6.7	6.6	6.5	2.3	6.9	7.1	7.0	7.3	7.1	7.1	2.1
T ₁₀	185	195.0	192	199.3	198.4	193.9	3.0	7.1	7.4	7.3	7.7	7.5	7.4	3.0	7.5	7.8	7.7	8.2	8.0	7.8	3.4
T ₁₁	162	200.6	202.0	202.0	205.0	194.3	9.3	6.9	7.6	7.7	7.8	7.6	7.5	4.7	7.8	8.1	8.0	8.1	8.1	8.0	1.5
T ₁₂	163	172.0	176.6	184.6	180.6	175.4	4.8	6.4	6.5	6.1	6.5	6.6	6.4	3.0	6.9	6.9	6.7	7.3	7.0	7.0	3.1
Mean	169.3	187.2	189.4	194.2	193.2	181.5	5.4	6.4	7.3	7.2	7.4	7.2	7.0	5.7	7.0	7.7	7.6	7.8	7.7	7.6	4.0
CD (P=0.05)	1.1	1.3	1.1	1.3	1.1	1.5		0.1	0.1	0.1	0.2	0.2	0.2		0.1	0.2	0.1	0.2	0.1	0.2	
CV(%)	5.5	6.2	5.3	3.8	4.8	4.7		9.8	7.1	8.6	6.9	6.8	6.9		9.0	6.6	7.3	6.0	6.4	6.5	

combination, showed a gradual annual increment in plant height and trunk diameter 3.0 m and 7.0 m in 9th year from 1.8 and 5.6 m in 5th year, respectively. However, leaf mould mulching along with increased level of organic manures resulted in better plant height and trunk diameter in each year. The effect of mulching and integrated nutrient combination may also be distinctly observed on annual shoot growth trend. The treatment combination (T₈) of leaf mould mulch and integrated nutrient comprising 50, 60, 70, 70 and 70 kg/tree of FYM and 10, 13, 16, 19 and 19 kg/tree of vermicompost along with inorganic source of N @ 50, 30, 10, 165 and 165g/tree; P₂O₅ @ 75, 80, 85, 178 and 178 g/tree and K₂O @ 250, 225, 250, 548 and 548 g/tree in 5th, 6th, 7th, 8th and 9th year, respectively, were found to be better for annual shoot growth with respective values of 68.9, 73.2, 79.0, 78.8 and 85.7 cm. This treatment combination was closely followed by T₅ (avg. 76.9 cm) and T₁₁ (avg. 75.1 cm). Black polyethylene mulch along with INM treatment also resulted in 72.9 cm (T₁₀) to 74.1 cm (T₄) mean annual shoot growth, however leaf mould was found to be better mulch irrespective of plant age. Similar trend was also observed at different age of trees from 5 to 9th year. As the quantity of integrated nutrients was increased annually as per estimated schedule of N, P and K doses, there was a distinct gradual increment in annual shoot growth as well with values of 60.6 cm in 5th year to 76.9 cm in 9th year, irrespective of treatments. This is the indication of proper supply of nutrition to the plant system through integrated combinations of nutrients and mulching.

Fruit physico-chemical parameters (Table 4) were significantly influenced by integrated nutrient management and mulching treatment. Treatment T₈ was again found to be effective for significantly better fruit weight (197.6g), fruit length (7.7cm), fruit diameter (8.3 cm), TSS (13.5%) and brix acid ratio (39.5) irrespective of plant age. Other

treatments, T₁₁ and T₅ comprising leaf mould and black polyethylene also resulted in comparatively better fruit physicochemical quality. However, leaf mould and black polyethylene (T₂ and T₁) mulches were also found to be effective in comparison to treatment without mulch (T₃) under recommended dose of inorganic fertilizers without vermicompost. Incorporation of vermicompost in sufficient quantities significantly improved fruit weight and size. Yield parameters (Table 6 and Fig 1) indicate that average fruit set and yield under leaf mould and integrated nutrient combinations ranged from 36.6% (T₅) to 39.5% (T₈) and 16.9 (T₅) to 19.1 kg/tree (T₈), respectively. This was closely followed by black polyethylene mulch in combination with INM. There was gradual increment in fruit set from 32.1 to 35.8% as well as yield from 4.1 to 24.1 kg/tree from 5th bearing year to 9th bearing year. Moreover, mean yield per tree in 8 and 9th year was relatively stable with 25.6 and 24.1 kg, respectively, which was very much higher than the preceding years. In these two years, treatment T₈ resulted in higher yield per tree, 31.8 and 30.6 kg/tree, respectively, which was a significant increase over the yield recorded in 5th year (5.3 kg/tree). Similarly, treatment T₁₀ and T₁₁ also resulted in significantly higher yield per tree. Average productivity was in the range of 27.0 MT/ha (T₅) to 31.4 MT/ha (T₈) under leaf mould and INM system, whereas, black polyethylene mulch and integrated nutrient combination resulted in 24.8 MT/ha (T₄) to 29.2 MT/ha (T₁₀). Productivity was low on trees which did not receive any type of mulching. Stability in productivity was also recorded in the 8 and 9th years with average productivity of 41.0 and 39.4 MT/ha, respectively, irrespective of treatments (Fig 2). Moreover, productivity was very much higher in treatments T₁₁ (52.9 and 51.8 MT/ha) and T₈ (50.8 and 53.3 MT/ha) in 8th and 9th year, respectively. Yield and productivity maximization in the 8th and 9th year over the

Table 5 Fruit Brix and acid ratio of cv. Starkirmson under integrated nutrient and mulching management

Treatment	TSS (°Brix)							Brix acid ratio						
	5th year	6th year	7th year	8th year	9th year	Mean	CV (%)	5th year	6th year	7th year	8th year	9th year	Mean	CV (%)
T ₁	9.5	11.5	12.5	12.7	12.5	11.7	11	17.3	25.0	30.5	33.4	36.8	25.1	93.7
T ₂	9.2	12.5	12.3	12.9	12.7	11.9	13	16.1	27.8	28.6	35.8	38.5	29.4	94.9
T ₃	8.8	10.8	11.3	11.7	11.8	10.9	11	14.7	20.4	24.6	29.3	28.8	23.5	88.7
T ₄	11.4	12.0	12.6	13.2	13.0	12.4	6	22.8	26.7	36.0	40.0	38.2	32.7	94.8
T ₅	11.5	12.5	12.8	12.9	13.2	12.6	5	21.7	32.9	38.8	43.0	41.3	35.5	97.6
T ₆	10.3	10.0	10.8	11.9	12.0	11.0	8	17.5	18.9	25.7	29.8	30.8	24.5	89.3
T ₇	13.0	13.4	13.3	13.6	13.4	13.3	2	26.0	36.2	39.1	42.5	40.6	36.9	95.0
T ₈	13.2	13.6	13.6	13.7	13.5	13.5	1	28.1	38.9	41.2	44.2	45.0	39.5	96.8
T ₉	11.2	11.3	11.7	11.9	12.2	11.7	4	20.0	22.6	30.8	34.0	32.1	27.9	91.0
T ₁₀	12.6	13.7	13.5	13.7	13.7	13.3	4	24.7	31.9	40.9	42.8	41.5	36.4	95.4
T ₁₁	13.0	13.5	13.4	13.6	13.7	13.4	2	28.9	37.5	41.9	45.3	44.2	39.6	97.0
T ₁₂	9.5	10.0	10.9	11.9	12.3	10.9	11	17.6	20.0	27.3	31.3	33.2	25.9	92.1
Mean	11.1	12.1	12.4	12.8	12.8		5.8	20.0	28.2	33.8	37.6	37.6		15.4
CD (P=0.05)	0.3	0.2	0.3	0.5	0.6	0.5		1.6	2.8	1.5	2.3	2.7	2.4	
CV(%)	13.4	11.0	7.9	6.1	5.3	8.4		24.1	25.3	19.3	15.9	14.2	12.9	

Table 6 Production parameters of cv. Starkrimson under integrated nutrient and mulching management

Treatment	Fruit set (%)					Yield (kg/tree)					Productivity (MT/ha)				
	5th year	6th year	7th year	8th year	9th year	Mean	CV (%)	5th year	6th year	7th year	8th year	9th year	Mean	CV (%)	
T ₁	30.2	35.2	34.3	37.2	36.2	34.6	7.8	3.0	7.2	7.6	24.5	22.5	13.0	75.7	
T ₂	32.5	37.5	36.5	38.5	37.5	36.5	6.4	3.2	7.7	7.9	27.6	25.6	14.4	78.6	
T ₃	25.6	29.5	30.2	32.2	30.2	29.5	8.2	2.0	4.3	5.5	15.3	13.3	8.1	72.5	
T ₄	34.4	38.4	37.4	38.4	38.4	37.4	4.6	3.7	7.6	8.4	27.4	25.4	14.5	76.1	
T ₅	36.0	36.0	35.6	36.0	39.0	36.5	3.8	3.5	7.5	7.9	29.8	27.8	15.3	81.5	
T ₆	28.6	30.0	32.7	33.7	31.7	31.3	6.5	3.0	5.0	5.8	17.3	18.3	9.9	74.0	
T ₇	36.5	38.5	38.1	40.1	37.9	38.2	3.4	5.5	8.1	8.7	29.8	26.8	15.8	73.1	
T ₈	35.0	39.0	37.2	42.2	38.9	38.5	6.9	5.3	8.8	9.5	31.8	30.6	17.2	74.9	
T ₉	28.5	31.5	30.7	34.4	32.5	31.5	6.9	4.0	6.0	6.8	20.2	18.2	11.0	68.4	
T ₁₀	35.5	37.0	37.8	39.5	37.5	37.5	3.9	5.7	8.5	8.9	30.4	31.0	16.9	74.9	
T ₁₁	34.8	38.0	38	40.0	38.6	37.9	5.0	5.4	9.0	9.4	33.1	32.4	17.9	76.6	
T ₁₂	27.3	32.5	30.5	32.5	31.5	30.9	7.0	4.3	5.8	5.9	20.4	17.4	10.8	70.0	
Mean	32.1	35.3	34.9	37.1	35.8	34.6	5.3	4.1	7.1	7.7	25.6	24.1	14.7	74.7	
CD (P=0.05)	0.8	0.7	0.7	0.7	0.8	0.7		0.2	0.3	0.4	0.3	0.2	1.8		
CV(%)	11.9	9.9	8.9	8.8	9.3	9.4		29.6	21.3	18.2	23.3	25.5	23.1		

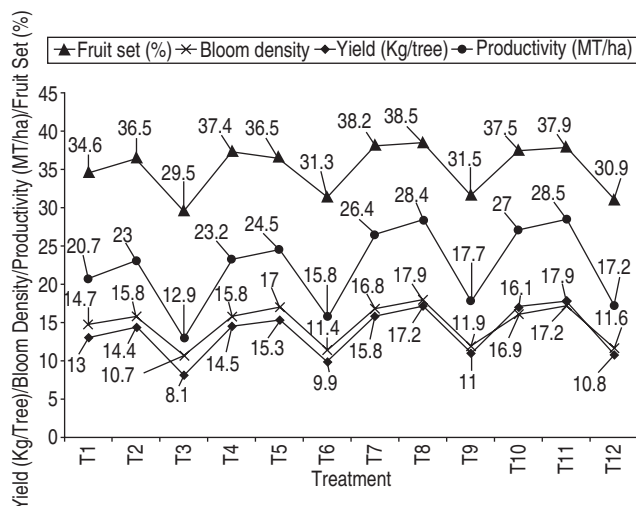


Fig 1 Bloom density, fruit set and yield parameters of cv. Starkrimson as affected by the INM and mulching.

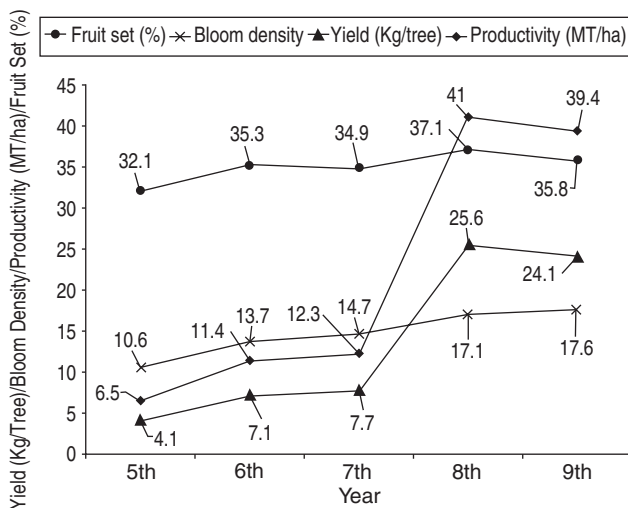


Fig 2 Annual trend of bloom density, fruit set and yield of cv. Starkrimson under INM and mulching.

preceding years may be due to formation of well managed canopy with higher lead area, better and more numbers of spur developments per unit length of twigs and increase in bloom density as also evident from the data of bloom and plant growth (Table 2 and 3). The main factor which resulted in higher yield is increase in bloom density because of more spur density apart from better fruit set and retention due to integrated nutrient management and mulching effect.

Balanced nutrition is very essential for apple vegetative and reproductive growth and it influences cropping through development of shoot and spurs, better photosynthesis, floral initiation, fruit set and yield (Stiles 1999). Moreover, leaf N always has a positive relation on floral buds, fruit set, crop density and yield (Tami *et al.* 1986). Dutta *et al.* (2010) and Verma and Chauhan (2013) reported that integrated nutrient combinations comprising organic and inorganic sources improves soil N, P and K and slow release of nutrient elements from organic sources facilitate better uptake. An integrated combination of NPK sources by incorporating

FYM and vermicompost as organic manure not only supplement major part of elemental NPK but also improved the soil micro-climate for ready availability of other macro and micronutrients, soil moisture status, enzymes and some phytohormones produce by microorganisms present in worms (Tomati *et al.* 1987, Edward 1998, Varga *et al.* 2004, Almeida *et al.* 2011, Geikloo and Shirmohammadi 2013). Moreover, organic mulches improves foliar nutrient content particularly Cu, Fe, Mn and Zn as well as soil pH and organic matter (Paszt *et al.* 2014). In the process of vermicompost formation many of the elemental nutrients are converted into more available forms such as nitrate or ammonium nitrate, exchangeable phosphorous and soluble potassium, calcium and magnesium which are readily taken by plants (Suthar and Singh 2008). Combination of organic manure, vermicompost along with chemical fertilizer have also been tested very effectively instead of sole application of full dose of chemical fertilizers in an apple orchard in Sirmour district of Himachal Pradesh (Raina *et al.* 2011). Leaf mould is formed after decaying for a longer duration under natural forest ecology and acts as a very good soil conditioner. Such type of organic mulches not only covers the tree basin soil, it allows rain drops to penetrate into the root zone gradually without disturbing the loose soil of the basin, thereby, minimizing the water loss from surface runoff as well as evaporation. Rich content of N (2-35), P (1.55-2.25%) and K (1.85-2.25%) in vermicompost (Sinha 2009) contributes the major share for supplementation of nutrients from inorganic sources. Beneficial effect of mulching over the clean basin was also well demonstrated in another study in Uttarakhand by Pandey *et al.* (2005), where, mulching improved annual extension growth, fruit retention and yield of apple.

In the present study also, apart from benefits from mulching, incorporation of increased level of organic manures might have played a pivotal role in improving leaf nutrient status especially nitrogen and potassium which in turn facilitated the translocation of photosynthates from source to sink and thereby, resulted into higher yield and quality fruits (Verma and Chauhan 2013). Supplementation of NPK by 25% with organic manures was also reported to be effective in enhancing yield, quality and nutrient use efficiency in Red Delicious apple (Singh *et al.* 2013).

The treatment T₈ was found to be better comprising leaf mould mulch and integrated nutrients: 50 kg/tree FYM + 10 kg/tree vermicompost + 50 g/tree N + 75 g/tree P₂O₅ + 250 g/tree K₂O in 5th years; 60 kg/tree FYM + 13 kg/tree vermicompost + 30 g/tree N + 80 g/tree P₂O₅ + 225 g/tree K₂O in 6th year; 70 kg/tree FYM + 16 kg/tree vermicompost + 10 g/tree N + 85 g/tree P₂O₅ + 250 g/tree K₂O in 7th year and 70 kg/tree FYM + 19 kg/tree vermicompost + 165g/tree N + 178 g/tree P₂O₅ + 548 g/tree K₂O in both 8 and 9th years. The productivity of cv. Starkrimson in 9th year under high density system was also very high (53.3 MT/ha) under INM and mulching. Reduction of FYM quantity by 50% and increasing the vermicompost dose also supplemented considerable amount of NPK requirement from inorganic

sources. It may be concluded that integrated nutrient management by incorporation of organic manures such as FYM and vermicompost in sufficient quantities supplement a considerable proportions of NPK generally supplied from inorganic sources, i.e. Urea, SSP or DAP and MOP and productivity of apple under HDP may be increased by adopting INM schedule.

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