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INFLUENCE OF CROP LOAD AND FOLIAR NUTRIENT SPRAYS ON GROWTH, YIELD AND QUALITY OF APPLE (*MALUS × DOMESTICA* BORKH.) CV. RED DELICIOUS

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ABSTRACT
In order to study effect of crop load and foliar nutrient sprays on growth, yield and quality of apple cv. Red Delicious a factorial experiment was carried out in Randomized Complete Block Design with three replications. The factors included of crop load with 3 levels (low, medium and high) and foliar nutrient sprays in 4 levels (urea (0.5%) solely, in combination with potassium sulphate (0.5%) , calcium chloride (0.3%) and both) spray on apple. Results showed that growth attributes, yield attributes and quality attributes were significantly influenced by crop load and nutrient sprays Maximum leaf area (33.70 cm^2), shoot extension growth (81.77cm), fruit weight (216.56g), TSS (13.69° Brix), return bloom intensity (82.58%) etc were recorded in trees with low crop load, which were at par with those of the medium crop load trees .Among nutrient sprays, maximum leaf area (33.06cm^2), shoot extension growth (80.89cm), TSS (14.18°Brix), total sugar content (12.39%), fruit length (7.92cm), fruit diameter (7.75cm), anthocyanin content (12.59mg/100g), return bloom intensity (81.45%) etc was recorded in trees sprayed with urea in combination with potassium. Results of the present investigation have led to the conclusion crop load management and proper dose and combination of foliar nutrient sprays may be helpful in increasing growth, yield and quality of apple.

INTRODUCTION

To meet market demand and attain profitable fruit production, apple growers must produce fruit of good quality while retaining the highest possible yields. The conflicting nature of these two goals requires accurate management of tree crop load. Excessively low crop loads will lead to reduced productivity, despite a larger fruit size; while, with too many fruits, the yield per tree and per hectare will be increased, but fruit size will be reduced. In addition, excessive crop loads can result in alternate bearing in many apple cultivars (Jimenez and Diaz, 2004). Successful fruit production is achieved by maintaining optimum crop load. Crop load management is, therefore, one of the most important orchard management techniques used to improve crop yield and quality in apple (Link, 2000; Byers, 2003).Regular cropping can also be achieved by nutrition management of the orchard. Nutritional elements that affect cropping consist of major and minor elements. Major elements include nitrogen, phosphorous, potassium, calcium etc. The minor elements include boron, manganese, zinc and copper. Nitrogen has both direct and indirect effects on the regularity of cropping. The direct effects include flower initiation and development, length of period of ovule receptivity, and fruit set. The indirect effects of N are those related to vigour of trees as indicated by shoot and spur growth and leaf area to support photosynthesis and the production of carbohydrate reserves (Boynton and Anderson, 1956). Calcium is the mineral nutrient, which has been most highly implicated in the quality of fruit particularly with respect to disorders, which affect storage. Potassium is often considered to be detrimental to fruit quality through interference with the uptake and utilization of Ca. Under deficient conditions, K applications may improve fruit quality. Phosphorous is important in the creation and stability of cell wall in fruits.

Fertilizer recommendations in fruit trees are based on the soil and leaf analysis. However, these recommendations do not take into account the expected crop load of the trees. Delicious group of varieties are more prone to irregular bearing. Therefore, fertilizer recommendations on such varieties should be governed by expected crop load of the trees during on and off year. Further, the nutrient removal by the trees with high crop load is higher as compared to the trees with low crop load (Awasthi and Kaith, 1990). Therefore the aim of this research was to adopt proper crop load and nutrient management in apple so as to have regular bearing of superior quality fruit.

MATERIALS AND METHODS

The present investigation was undertaken to study the effect of crop load and nutrient sprays on growth and quality of apple *Malus × domestica*Borkh cv. Red Delicious" at private orchard, Sopore (Jammu & Kashmir). The trees selected for the present study were of more than 15years age of uniform vigour and were grafted on seedling rootstock. Three crop loads viz, low medium and high were maintained on the selected trees having 1.5-2.0 fruits, 2.0-2.5 fruits and 2.5-3.0 fruits cm^{-2} TCSA respectively. The selected trees were sprayed with 1) Urea @ 0.5 %, 2) Potassium sulphate @ 0.5 % + Urea @ 0.5 % , 3) Calcium chloride @ 0.3 % + Urea @ 0.5 %, 4) Urea @ 0.5 % + potassium sulphate @ 0.5 % + calcium chloride @ 0.3 %. In order to avoid incompatibility sprays were conducted separately on a tree with a gap of one day. The number of treatments was twelve. The treatments were allocated in a Randomised Complete Block Design with three replications in a factorial experiment. Thus total number of trees was thirty six. Observation on leaf area was recorded from ten fully mature leaves which were taken from mature shoots of current season growth in the month of July and measured with the help of Systronics leaf area metre 211. Observations on fruit size, fruit weight were based on random ten fruit samples. Fruit quality parameters, viz, TSS, total sugars, fruit acidity and anthocyanin content were determined as per standard procedures given by A.O.A.C (1980). Fruit firmness was estimated by penetrometer. Observations on return bloom intensity was taken by tagging four branches each of one metre down from the base of one year old wood and counting the number of vegetative and floral buds and return bloom intensity was calculated using the formulae given by Westwood (1988).

RESULTS AND DISCUSSION

The data presented in Table 1 suggest that crop load and nutrient sprays had significant influence on leaf area and annual shoot extension growth. Highest leaf area (33.70 cm^2) and annual shoot extension growth (81.77 cm) was observed on trees with low crop load. Among nutrient sprays highest leaf area (33.06cm^2) and annual shoot extension growth (80.89cm) was recorded on trees sprayed with urea in combination with potassium. In light cropping trees there is less competition and the vegetative organs utilize more photosynthates resulting in their increased vegetative growth as indicated by increasing leaf area and annual shoot extension growth. These are in agreement with those of Wunsche and Palmer (2000) who found that heavily cropping Braeburn trees on M.26 rootstock had 67% less leaf area than deblossomed trees. The higher leaf area and annual shoot extension growth under urea in combination with potassium application may be attributed to the fact that nitrogen plays an active role in cell division and cell elongation and potassium is an important solute in expanding cells and expansive growth is very sensitive to potassium deficiency (Faust, 1989).These results are in agreement with the findings of Singh *et al*. (2005) who recorded an increased shoot length of mango tree on applying potassium. Among the various treatment combinations trees with low crop load sprayed with urea in combination with potassium resulted in maximum leaf area and annual shoot extension growth.

Perusal of data in Table 2 reveals that both crop load and foliar nutrient sprays significantly affected fruit yield, fruit weight, fruit length, fruit diameter and fruit firmness of apple. Fruit yield increased with increase in crop load. Maximum fruit yield (119.50 kg/tree) was recorded in trees with high crop load and minimum fruit yield (72.98 kg/tree) was recorded from trees with low crop load. Trees with high crop load had a high fruit number per tree. Similar findings were confirmed by Treder (2008) who found a positive correlation between fruit yield and crop load. As crop load increased fruit weight, fruit length and fruit diameter showed decreasing trend. Fruits from trees with low crop load were heavier (216.56 g) with

Table 1: Leaf area and annual shoot extension growth as influenced by crop load and foliar nutrient sprays

Treatment	Leaf area (cm^2)	Annual shoot extension growth (cm)
Crop load		
C_1 : Low crop load	33.70	81.77
C_2 : Medium crop load	29.40	71.60
C_3 : High crop load	27.50	66.59
CD at 5%	2.56	8.25
Foliar nutrient sprays.		
N_1 : Urea	27.93	67.28
N_2 : Urea + Potassium	33.06	80.89
N_3 : Urea + Calcium	29.27	69.96
N_2 : Urea + Potassium + Calcium	30.63	75.14
CD at 5%	2.95	9.53
Interaction effect		
C_1N_1	30.05	72.50
C_1N_2	36.62	98.25
C_1N_3	34.02	73.12
C_1N_4	34.19	83.17
C_2N_1	28.36	68.67
C_2N_2	31.98	74.58
C_2N_3	28.01	68.83
C_2N_4	29.26	74.33
C_3N_1	25.38	60.67
C_3N_2	30.57	69.83
C_3N_3	25.79	67.92
C_3N_4	28.44	67.92
CD at 5%	5.12	16.49

Table 2: Fruit yield, fruit weight, fruit length, fruit diameter and fruit firmness of apple as influenced by crop load and foliar nutrient sprays

Treatment	Fruit yield (Kg/tree) Crop load	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit firmness (Kg/cm^2)
C_1 : Low crop load	72.98	216.56	7.79	7.59	7.17
C_2 : Medium crop load	100.01	207.12	7.49	7.43	7.23
C_3 : High crop load	119.50	189.17	7.14	6.92	8.12
CD at 5%	8.00	8.90	0.34	0.19	0.85
Foliar nutrient sprays.					
N_1 : Urea	93.59	199.55	7.34	7.37	6.86
N_2 : Urea + Potassium	109.70	225.42	7.92	7.75	6.82
N_3 : Urea + Calcium	85.90	189.85	6.83	6.54	8.62
N_2 : Urea + Potassium + Calcium	100.81	206.31	7.81	7.59	7.74
CD at 5%	12.41	14.02	0.39	0.23	0.90
Interaction effect					
C_1N_1	72.50	202.96	7.81	7.72	6.52
C_1N_2	82.50	241.41	7.99	7.98	6.47
C_1N_3	67.78	201.91	7.42	6.99	8.24
C_1N_4	69.17	219.95	7.94	7.70	7.45
C_2N_1	98.34	192.37	7.31	7.65	6.64
C_2N_2	118.34	228.37	7.96	7.93	6.65
C_2N_3	78.34	189.58	6.81	6.47	8.40
C_2N_4	105.01	218.16	7.90	7.66	7.23
C_3N_1	109.92	191.33	6.90	6.75	7.41
C_3N_2	128.26	202.48	7.82	7.35	7.33
C_3N_3	111.59	174.05	6.27	6.15	9.22
C_3N_4	128.25	180.83	7.59	7.43	8.53
CD at 5%	19.34	32.94	0.69	0.39	1.87

Table 3: TSS, total sugar content, titrable acidity and anthocyanin content as affected by crop load and foliar nutrient sprays

Treatment	TSS (°Brix)	Total sugars (%)	Titrable acidity (%)	Anthocyanin (mg/100g)
Crop load				
C_1 : Low crop load	13.69	11.97	0.28	10.59
C_2 : Medium crop load	13.17	11.17	0.25	11.99
C_3 : High crop load	11.62	10.17	0.23	11.92
CD at 5%	0.87	0.86	0.02	0.60
Foliar nutrient sprays.				
N_1 : Urea	12.74	10.82	0.20	10.95
N_2 : Urea + Potassium	14.18	12.39	0.25	12.59
N_3 : Urea + Calcium	11.50	9.70	0.29	10.68
N_2 : Urea + Potassium + Calcium	12.89	11.50	0.26	11.79
CD at 5%	1.00	0.90	0.04	0.69
Interaction effect				
C_1N_1	13.66	12.10	0.22	10.51
C_1N_2	15.46	13.54	0.27	11.19
C_1N_3	12.12	10.04	0.32	10.25
C_1N_4	13.53	12.21	0.30	10.41
C_2N_1	13.09	10.84	0.20	11.35
C_2N_2	14.53	11.89	0.25	13.73
C_2N_3	11.89	10.01	0.29	10.80
C_2N_4	13.19	11.94	0.26	12.11
C_3N_1	11.46	9.53	0.19	10.99
C_3N_2	12.56	11.76	0.24	12.87
C_3N_3	10.49	9.05	0.27	10.99
C_3N_4	11.96	10.35	0.21	12.84
CD at 5%	1.74	1.72	0.06	1.20

maximum length (7.79 cm) and diameter (7.59 cm) being at par with that from trees with medium crop load, while as fruits from trees with high crop load were lighter (189.17g) with minimum length (7.14 cm) and diameter (6.92 cm). In trees with low crop load leaf : fruit ratio was higher. More nutrients were available to the fruits as competition among fruits was less. This may have induced an increase in cell division. These factors lead to an increase in fruit size and weight. These results are in agreement with the findings of Embree *et al.*, (2007). Maximum flesh firmness (8.12 kg/cm^2) was obtained in fruits from trees with high crop load which was at par with fruits on trees with medium crop load while minimum flesh firmness (7.17 kg/cm^2) was recorded in fruits from trees with low crop load (Table 2). The reduced flesh firmness in fruits

Table 4: Return bloom intensity of apple as affected by crop load and foliar nutrient sprays:

Treatment	Return bloom intensity (%)
Crop load	
C_1 : Low crop load	82.58
C_2 : Medium crop load	77.56
C_3 : High crop load	71.34
CD at 5%	2.07
Foliar nutrient sprays.	
N_1 : Urea	69.78
N_2 : Urea + Potassium	78.79
N_3 : Urea + Calcium	78.62
N_2 : Urea + Potassium + Calcium	81.45
CD at 5%	3.01
Interaction effect	
C_1N_1	77.33
C_1N_2	84.00
C_1N_3	84.30
C_1N_4	84.69
C_2N_1	71.00
C_2N_2	79.69
C_2N_3	77.56
C_2N_4	82.00
C_3N_1	61.00
C_3N_2	72.69
C_3N_3	74.00
C_3N_4	77.67
CD at 5%	5.03

on trees with low crop load may be attributed to increase in fruit size in light cropping trees as a result of which their cell walls expand and proportion of cell wall material decreases in relation to total fruit volume. Moreover the large sized fruits are poor in calcium content as a result of which firmness decreases. These findings are in conformity with those of Link, 2000. In response to foliar sprays highest fruit yield (109.70 kg/tree), fruit size (7.92 and 7.75 cm) and fruit weight (225.42 g) were recorded on trees sprayed with urea in combination with potassium. Potassium plays an important role in increasing photosynthetic efficiency of the plant and is involved in enhancing growth of fruit plant resulting in higher yield, fruit weight and fruit size. These results are in agreement with the findings of Dar *et al.* (2012) who observed that fruit weight and fruit size of pear increased in relation to potassium fertilization. Maximum fruit firmness (8.62 kg/cm^2) was recorded in fruits on trees sprayed with urea in combination with calcium. This may be attributed to the role of calcium in maintaining membrane integrity of cells and its importance in maintaining structural integrity of cell walls. Moreover, calcium is needed for the synthesis of pectic substances which enhance fruit firmness. These results are in agreement with the findings of Wojcik *et al.,* (2010) and Bisen *et al.* (2014).Among the crop load and nutrient combinations highest fruit weight, fruit length and fruit diameter was observed on trees with low crop load sprayed with urea in combination with potassium. Fruit firmness was highest on trees with high crop load sprayed with urea in combination with calcium.

Chemical characteristics of fruit like TSS, total sugars, titrable acidity and anthocyanin content were significantly affected by crop load and foliar nutrient sprays (Table 3). Maximum TSS (13.69 ^{o}Brix), total sugar (11.97%) and acidity (0.28%) were obtained from fruits from trees with low crop load found to be at par with those of fruits harvested from trees with medium crop load while minimum TSS (11.62°Brix), total sugar content (10.17%) and acidity (0.23%) were obtained from fruits on trees with high crop load. The suppressive effect of high crop load on TSS, total sugars and acidity is probably due to the shortage of carbohydrate supply for the developing fruits. Moreover low crop load increases the ratio between leaf area and fruit number, resulting in an increased availability of assimilates and potentially a high TSS, total sugars and acidity at harvest. These results are in agreement with the findings of Meland (2009), Patel *et al.* (2014). Maximum anthocyanin content (11.99 mg/100g) was recorded in fruits on trees with medium crop load while minimum anthocyanin content (10.59 mg/100 g) was recorded in fruits on trees with low crop load (Table 3). Trees with low crop load have an enhanced vegetative growth. This enhanced vegetative growth results in shading of fruits. Since light is necessary for anthocyanin synthesis, the fruits from trees with low crop load have low anthocyanin content. These results are in agreement with Daugaard and Grauslund (2000).

In response to foliar nutrient sprays maximum TSS (14.18ºBrix)), total sugar content (12.39%) and anthocyanin content (12.59 mg/100 g) was recorded in fruits from trees sprayed with urea in combination with potassium, while minimum TSS (11.50°Brix), total sugar (9.70 %) and anthocyanin content (10.68 mg/100 g) was recorded in fruits from trees sprayed with urea in combination with calcium. This may be attributed to the fact that potassium plays an important role in sugar biosynthesis and translocation and 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 Hunsche *et al.* (2003). Acidity was found to be highest in fruits on trees sprayed with urea in combination with calcium (0.29%) and lowest (0.20%) in fruits harvested from trees sprayed with urea alone. This may be attributed to the ability of calcium to maintain cellular integrity by controlling membrane permeability as a result of which H^+ ions cannot leach out from the cytosol, thus maintaining higher levels of acidity. This is in confirmity with the findings of Singh *et al.* (2002) with peaches. Among the various crop load and nutrient combinations significantly maximum TSS, total sugar content was recorded in fruits harvested from trees with low crop load sprayed with urea in combination with potassium. Acidity was found to be maximum on fruits harvested from trees with low crop load sprayed with urea in combination with calcium. Trees with medium crop load sprayed with urea in combination with potassium produced fruits with significantly higher anthocyanin content.

Data enumerated in Table 4 reveals that crop load and foliar nutrient sprays had a significant effect on return bloom intensity of apple. Return bloom intensity was highest (82.58%) on trees with low crop load which was statistically at par with that on trees with medium crop load and lowest (71.34%) on trees with high crop load. This may be attributed o the fact that in heavy crop load trees seeds of the young developing fruits are rich source of growth hormones (gibberellins) which diffuse to the bourse shoot where they inhibit flowering. Moreover, seeds compete with other plant tissues for the compound florigen produced by leaves and thus inhibit flowering. Similar effects were observed by Robinson *et al*. (2009) who showed a strong suppressive effect of increasing crop load on return bloom the next year .Among nutrient sprays highest return bloom intensity (81.45%) was recorded on trees sprayed with urea in combination with potassium and calcium. This may be attributed to the fact that N has both direct and indirect effect on regularity of cropping (Stiles, 1999) and potassium plays an important role in increasing photosynthetic efficiency of plant, as a result some of the photosynthates are utilized for the next year's flower bud differentiation.

It may be concluded that proper nutrient management of a fruit crop should not be based only on soil and plant analysis, but the crop load should also be taken into consideration. Results of the present investigation have led to the conclusion that trees with medium crop load should be sprayed with urea + potassium to get higher yield of good quality fruit.

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