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Impact of split application of fertilizer at various growth stages on Kinnow productivity under semi-arid irrigated ecosystem

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ABSTRACT

A study was conducted at the experimental orchard of the Department of Horticulture, CCS Haryana Agricultural University, Hisar to study the impact of split application of recommended dose of N @ 800 g; P_2O_5 @ 320 g and K_2O @ 105 g/plant/year at various growth stages in Kinnow orchard for consecutive three years. The soil of the experimental site was sandy loam, free from $CaCO_3$, poor in organic carbon, medium in phosphorus and high in potash content. The results of pooled data showed that application of nitrogen three times, 40% in February and 30% each in April and July; phosphorus two times, 50% each in February and April; and potash three times, 40% each in February and April and 20% in September reduced pre-harvest fruit drop (21.16%), increased number of fruits (10.19%) and increase in fruit yield about 10.29% with good quality in terms of TSS and peel thickness over control (recommended practice). Split application of N & K increased uptake, whereas, reverse was observed in phosphorus. The leaf N and K contents were highest when 30% of total N and 20% of total K/plant/year were applied in July (pre-autumn flush stage). Hence, there is a need to revise the current recommendation in response of K dose and frequency of N & K application on phenological stages to get optimum productivity of Kinnow orchard on sandy loam soils poor in organic carbon under semi-arid irrigated ecosystem of north western zone of India.

Keywords: Fertilizer, growth stage, Kinnow mandarin, productivity, semi-arid irrigated conditions.

INTRODUCTION

The introduction of Kinnow, a mandarin hybrid, gained popularity within a short span of time by replacing sweet oranges cultivation due to its high yielding potential. It showed a good promise and commercially success in North Indian states like Punjab, Haryana and Rajasthan falling under subtropical climate with distinct winter season. Mandarins constitute the bulk of citrus exports from India. Recently, Kinnow was exported from Punjab and Rajasthan to Sri lanka, UK, and Gulf countries. Unfortunately, the production from Kinnow orchards is very low than standard. One of the main reasons for low citrus orchard productivity in South-Western zone of Haryana is poor nutrition because of improper use of fertilizers input in respect of time, combination/ different NPK ratio. Fertilizers are being used by the growers at the start of spring flush and just after fruit set in April, thereafter, no fertilizer is applied up to harvesting in January. Kinnow is a heavy feeder of nutrients and water because of shallow root system and prolific bearing. After initial few years of good productive periods, the productivity and plant health starts declining and by then it becomes near impossible to eradicate multi-nutrient deficiency which eventually leads to citrus decline and reduction in yield and heavy fruit drop due to nutrient deficiency.

Since, citrus is a tree and has growth in cycles, therefore until or unless, fertilizer application program is properly designed according to growth cycle, it is not possible to improve the plant health and fruit production substantially (Alva *et al.*, 1; Zaman and Schumann, 21). Hence, efficient use of fertilizer has become a first-order concern in modern citrus production system. The use of fertilizers by plant involves several steps, including uptake, assimilation, translocation, recycling and remobilization (Masclaux-Daubresse *et al.*, 9). Several factors affect fertilizer N uptake efficiency, including plant demand for N (Weinbaum *et al.*, 19), the rate, timing of application, the form of N applied and soil type. Other factors inherent to plant as size and depth of root system, that determine the plant ability to intercept N before leached below the root zone (Scholberg *et al.*, 16) can also influence NUE. According to Stassen *et al.* (17) the seasonal pattern of N uptake can be used for scheduling the timing and rate of application. In this way, most efficient application is, therefore achieved, when synchronized with tree N demand. Saleem *et al.* (14) observed that split application of compound fertilizers was more effective than single application of the same or simple fertilizer in Kinnow. Seasonal variation in N uptake occurs, with the uptake appearing to be highest during period of active shoot growth (Maust and Williamson, 10; Menino *et al.,* 11).

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Nevertheless, other phenological important stages may be identified and used as selection criteria to evaluate different fertilizer management strategies. Research efforts during the past decade have focused on the identification of several management practices like type of fertilizers, rate of application and method of application that improve the fertilizer use efficiency. Current citrus best management practices recommend fertilizer dose based on leaf tissue and soil analysis, instead of routine application (Boman *et al.*, 3). Moreover, an appropriate timing, which maintain the supply of nutrients over the growth cycle constitute one of the most relevant strategies in improving fertilizer use efficiency (Martinez-Alcantara *et al*., 8) as well as sustainable productivity. Keeping in view the above facts, the present investigation was carried out with the objective to sustain the Kinnow productivity by applying different ratio of NPK at various growth and phenological stages.

MATERIALS AND METHODS

The field experiment was conducted at the experimental orchard of the Department of Horticulture, CCS HAU, Hisar located at latitude 29.10° N, longitudes 75.46° E and at an altitude of 215.2 m above sea level. The climate of the experimental site is characterized as semi-arid subtropical with hot and dry summer and cool winters. The mean annual rainfall is 400 mm, out of which around 90% is received during monsoon (July-September). The physico-chemical properties of experimental soil are given in Table 1. The texture of the soil was sandy loam with $CaCO_3$ < 1.0%. The soil had almost neutral pH with mild EC ranged from 0.25-0.45 dS m^{-1} and deficient in organic carbon (0.15-0.37%). The available P and K concentrations in soil ranges from 15-25 kg/ha and 240-333 kg/ ha, respectively. Canal water was used as flood irrigation and water table level was about 4 m deep.

The citrus plant used in the study was Kinnow mandarin budded on rough lemon (*Citrus jambhiri* Lush) rootstock at a spacing of 6 m × 6 m. The experiment was conducted for three consecutive years (2011-12, 2012-13 and 2013-14). Twenty trees subjected to the same cultural practices were chosen nearly similar in growth, vigour and health. Four nutritional treatments were designed to apply the same amount 800 g N, 320 g P_2O_5, and 105 g K_2O/ tree/year, which is the recommended dose of fertilizer of the region. Total dose of fertilizer was splited into four different percent ratio of N: P: K and applied at four phenological stages, *i.e.* spring flush stage (February), cell division stage (April), rainy season/ pre-autumn flush stage (July) and autumn flush stage (September) in all the treatments (Table 2). In control, RDF (N @ 800g; P_2O_5 @ 320 g and K_2O @ 105 g/ plant/year) was applied in two splits, *i.e.* half dose of nitrogen and full doses of phosphorus and potassium in February and remaining half nitrogen in April. A complete randomized block design was followed with five replications taking one plant per replication. The data (pooled mean data of three years) pertaining to various parameters was analyzed statistically as per the procedure of (Panse and Sukhatme, 12). FYM was applied in December at the rate of 20 kg/ plant. N, P & K were applied in form of urea, diammonium phosphate and muriate of potash, respectively.

Pre-harvest fruit drop was calculated by counting the number of dropped fruits daily from September onward till harvesting from each plant under experiment and computed as pre harvest fruit drop (%). Harvesting of fruit was achieved in the last week of December and yield (kg/plant) was recorded by weighing on electronic balance. Numbers of fruits/ plant were counted at harvesting and average fruit weight was calculated by dividing the yield to the number of fruits. At harvest, sample of five representative fruits of each tree were devoted to determine the fruit physico chemical characteristics. Peel thickness was recorded by measuring the peel of the fruit at the equator of fruit to right angle with the help of Vernier calipers and averaged. Peel of the fruit

Table 1. Physico-chemical properties of soil profile of the experimental site.

Soil depth (cm)	Texture	pH (1:2)	EC (dS m^{-1})	Organic carbon (%)	Available phosphorus (kg/ha)	Available potash (kg/ha)
0-15	Sandy loam	7.53	0.27	0.37	23.0	333
15-30	Sandy loam	7.60	0.25	0.30	25.0	264
30-60	Sandy loam	7.67	0.26	0.27	22.0	278
60-90	Sandy loam	7.73	0.29	0.15	20.0	240
90-120	Sandy loam	7.60	0.34	0.15	17.0	278
120-150	Sandy loam	7.60	0.40	0.15	20.0	252
150-200	Size	7.57	0.45	0.15	15.0	240

Table 2. Doses of applied nitrogen, phosphorus and potash at various phenological stages of Kinnow mandarin.

Treatment	Per cent RDF application at different phenological stage											
	Feb (spring flush)			April (cell division stage)			July (rainy season flush)			September (autumn flush)		
	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
T_1	40	100	40	20	0	40	20	0	20	20	0	0
T_2	40	50	40	30	50	40	30	0	0	0	0	20
T_3	40	40	40	30	30	20	0	30	20	30	0	20
T_4:contol	50	100	100	50	0	0	-	-	-	-	-	-

was separated and weighed and expressed as peel content (%). After peeling the same fruits were used for extracting the juice and expressed as juice content (%) on weight basis. The percent acidity and ascorbic acid were determined as suggested by (AOAC, 2). Total soluble solids (TSS) was determined with the help of Abbe's hand refractometer (0-32°Brix). Leaf samples were collected from each plant in the month of October by selecting 3rd and 4th leaf terminally from spring flush non-fruiting shoots at chest height. The known amount of powdered material was digested in diacid mixture of H_2SO_4: $HClO_4$ in the ratio of 4:1 for estimation of N,P,K, whereas, for Zn content diacid mixture of HNO_3:$HClO_4$ in the ratio of 4:1 was used. Nitrogen was estimated with Nessler's reagent method and phosphorus with Vandomolybdate yellow colour method as per standard procedure (Jackson, 7). Potash was determined with flame photometer (Piper, 13) and zinc was estimated with atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

Fruit yield is a good index of orchard productivity and fruit retention, fruit weight and number of fruits harvested is the good indicator of yield. Among various treatments, T_2 was found significantly most superior in increasing the fruit yield (119.57 kg/plant) over the remaining treatments, which were otherwise on par with each other (Table 3). The minimum yield (107.44 kg/plant) was found in treatments T_4 (control/ farmers' practice). Average fruit weight could not be affected significantly by any of the treatments; however, numerically maximum fruit weight (179.96 g) was achieved in T_1 and minimum (172.12 g) in T_4 (control/ farmers' practice). Treatment T_2 was found significantly most effective in reducing pre-harvest fruit drop (8.01%) closely followed by T_3 (8.16%) as compared to T_1 (9.34%) and T_4 (10.16%). Similarly, T_2 was also observed significantly superior in increasing number of fruits (681.07) harvested to remaining treatments, which were otherwise on par with each other. The minimum number of fruits (607.93) was harvested in T_1.

The results clearly shows that application of N @ 800 g/tree/year three times, 40% in Feb, 30% in April and 30% in July; P_2O_5 @ 320 g/tree/year two times, 50% in Feb. and 50% in April and K_2O @ 105 g/tree/year three times, 40% in Feb., 40% in April and 20% in September reduced the pre-harvest fruit drop to the tune of about 21.16%, increased number of fruit harvested/ plant (10.19%) and yield (10.29%) over control T_4 (control/ farmers' practice). The maximum weight of the fruit in treatment T_1 may be due to less number of fruits harvested and secondly, due to more content of K in leaves as more potash content in citrus leaves is directly related to fruit size. Hifny *et al.* (6) reported the highest fruit weight of Valencia oranges when receiving 50% of total N/tree/ year during period of pre-spring flush or the period of fruit cell division stage and subsequently stimulation of photosynthesis intensity. The reduced fruit drop in T_2 was due to more uptake of N and thus reduced competition for vegetative and reproductive growth with July application of nitrogen. Similarly, Saleem *et al.* (14) observed minimum fruit drop with split application of 2 kg compound fertilizers (CF) per tree

Table 3. Effect of split application of nutrients doses on fruit drop and yield of Kinnow mandarin (pooled mean).

Treatment	Pre-harvest fruit drop (%)	Fruit wt. (g)	No. of fruits harvested/ plant	Yield (kg/tree)
T_1	9.34	179.96	607.93	109.18
T_2	8.01	174.83	681.07	119.57
T_3	8.16	175.40	633.13	111.94
T_4	10.16	172.12	618.07	107.44
CD at 5%	0.91	NS	33.45	7.89

and 1.0 kg urea in August in Kinnow, while fruit drop was negligible in later months. These results are in accordance with those of Yaseen and Ahmed (20) who also showed increase in fruit yield of Kinnow over control with the application of NPK fertilizer (200-150-250 g/ tree) at three times, *i.e.* before new flush at last week of Jan., mid of April and end of July with foliar spray of multi-nutrients.

It seems that application of N in three splits, *i.e.* in Feb, April and July resulted in better yield. This may be due to more uptake of N when applied in July as compared to September. In fact nitrogen is the key component in mineral fertilization applied to citrus groves, since it influences tree growth, fruit production as well as fruit quality than any other treatments (Zekri and Obreza, 22). About 40% of annual vegetative growth in Kinnow takes place during July-August, which requires nitrogen for growth. If there is less availability during rainy season growth (July-August) then poor uptake of N and there will be remobilization of metabolites from spring growth leaves, which hinders in fruit growth and ultimately more pre-harvest fruit drop and reduced yield, which further had adverse effect on flowering and fruiting in next season (Dalal *et al.*, 4). September application of nitrogenous fertilizers was not effective as it did not show response on yield and uptake of nitrogen in T_1 & T_3. This shows lower uptake of N in September due to reduced root activity in the autumn and winter. Similarly, adding of 50% of total given N/tree/year at pre-autumn flush stage caused the most increase in fruit yield of Valencia budded on sour orange compared with other phenological stages and control (Hifny *et al.*, 6). Despite other factors, improvement in yield can also be attributed to reduced fruit drop preventing the plant from nutritional deficiencies and disorders. Application of nitrogen and potash in July and September, respectively strengthen the plants by inducing an enhancement in physiological response of the plants.

Peel thickness, TSS, juice content, juice acidity and ascorbic acid are the most important parameters used to determine Kinnow quality. Just unlike the yield response, split application of N,P,K had significantly minor impact on these parameters as compared to control/ farmers' practice. Among fruit quality parameters, peel thickness, TSS, and ascorbic acid differed significantly, whereas, peel content, juice content and acidity differed non-significantly with various treatments (Table 4). Peel thickness increased significantly in T_2 (3.77 mm) over the remaining treatments, whereas, thinnest peel (3.40 mm) was observed in T_3. Similarly, numerically maximum peel content (22.16%) was found in T_2 and minimum (21.11%) in T_3. Maximum juice content (50.29%) was measured in T_3 and minimum (47.86%) in T_4 (control/ farmers' practice). Treatment T_2 was found significantly most effective in increasing the TSS (10.72°Brix) over the other treatments. Treatment T_4 and T_1 were found significantly on par with each other and significantly higher in increasing the TSS over T_3. Treatment T_1 showed numerically least acidity (0.96%) and T_2 the highest acidity (1.03%). The maximum ascorbic acid content (23.12 mg/ 100 ml of juice) was estimated in T_4, which was also significantly highest over other treatments, whereas, treatments T_1, T_2 and T_3 were at par with each other. The minimum ascorbic acid content (21.47 mg/100 ml of juice) was estimated in T_3.

The results related to biochemical attributes of Kinnow mandarin clearly indicates the importance of split application of N,P&K, especially the third application of N & K in July and September. Nutrients applied in split dose positively influence the fruit quality parameters. Fruit quality in Kinnow improved with the increase in TSS content, whereas, juice and acidity content were not affected significantly. This may be due to higher N: K ratio in leaves in T_2 as compared to other treatments. The improvement in fruit physico-chemical parameters may be due to the fact that split nutrient application improves the nutrient uptake by the plant and this imparted the beneficial influence on plant growth and ultimately fruit quality parameters. Application of N and K in late stages of fruit growth (July and September) increased nitrogen and potash in leaves, which have the positive

Table 4. Effect of split application of nutrient doses on fruit quality of Kinnow mandarin (pooled mean).

Treatment	Peel thickness (mm)	Peel content (%)	Juice (%)	TSS (°Brix)	Acidity (%)	Ascorbic acid (mg/ 100 ml juice)
T_1	3.45	21.96	48.75	10.31	0.96	21.58
T_2	3.77	22.16	49.68	10.72	1.03	22.22
T_3	3.40	21.11	50.29	9.91	1.00	21.47
T_4	3.44	21.56	47.86	10.35	0.98	23.12
CD at 5%	0.14	NS	NS	0.29	NS	0.87

effect on many important plant structure, genetic and metabolic compounds in plant cell (Don, 5) and enhanced photosynthesis, consequently there will be more production of assimilates. These assimilates are depicted in terms of increases TSS, juice content and acidity. Similar increase in peel thickness showed more response when 50% of total N/tree/year was applied in pre-autumn stage and increase in TSS content when applied any of the phenological stage except control (Hifny *et al.*, 6) in Valencia sweet orange .The decrease in ascorbic acid content with split application of nutrients as compared to control in present study may be due to increased juice content and fruit weight.

Leaf nitrogen and potash contents differed significantly, whereas, phosphorus and zinc differed non-significantly with various treatments (Table 5). Maximum nitrogen content (2.55%) was found in treatment T_2, which was significantly superior to T_4 (control/ farmers' practice) and on par with other treatments. Minimum nitrogen content (2.33%) was observed in T_4 (control/ farmers' practice). Numerically maximum phosphorus content (0.138%) was found in treatment T_1 and minimum (0.19%) in T_3. Potash content increased in all the treatments over T_4 (control/farmers' practice) but could not reach to the level of significance except T_1. Maximum potash content (0.705%) was observed in treatment T_1 which was found at par with T_3 (0.644%) and T_2 (0.59%). Similarly, zinc content increased in all the treatments over T_4 (control/ farmers' practice) but could not attain the level of significance. However, the numerically maximum zinc content (31.18 ppm) was observed in treatment T_1 and minimum (28.64 ppm) in T_4 (control/ farmers' practice).

Split application of N & K increased the uptake in Kinnow orchard, whereas, reverse was observed in phosphorus. However, the leaf N content was in optimum range in all the treatments but it was on higher side when 30% of total nitrogen/tree/year was applied in July (pre-autumn flush stage) in treatmentT_2, whereas, N uptake was lower when 20 and 30% of total N/tree/year was applied in September (autumn flush stage) in T_1 & T_3. This shows that nitrogen required by citrus plants is more during rainy season growth flush in July as compared to autumn season growth as nitrogen is essential for vegetative growth of plant. Martinez-Alcantara *et al.* (8) reported that fertilizer N uptake clearly differed among periods, being the lowest values recorded at flowering, while increased significantly later on at fruit set and growth periods of citrus. About 40% of the annual vegetative growth in Kinnow took place in rainy season and even <10% during autumn season flush (Dalal *et al.*, 4). As the split application of nutrients enhanced the nutrient availability to the plant especially N and K, besides it helps in efficacious regulation of stomatal conductance (Traiz and Zeiger, 18), which thus caused an increment in nutrients absorption efficiency of the plant. In the present study if P is applied in more than one split its uptake in leaves decreased in treatments T_2 & T_3. Phosphorus helps in root activity which is most in summer season in citrus. This shows that P should be applied in the early stages of the growth of the citrus plant. In contrary, Salik *et al.* (15) observed that when fertilizers were applied in April or July, not much improvement was noted and results were similar to control in Kinnow. Potash content in all the treatments were found in deficient range, whereas, it was in excess in soil. This shows that potash present in soil is not available to the Kinnow plant and also K applied by the farmers is not sufficient to supplement the requirement of K by the Kinnow orchards. However, the split application of K increased uptake and uptake was most when 20% of total K/tree/year was applied in July (T_1). However, when 20% of K was applied in September there was non-significant increase in K content (T_2). Saleem *et al.* (14) also reported that split application of compound fertilizers was more effective than single application of the same or simple fertilizers. Hence, it is clear that N & K application should be avoided in September due to poor uptake, whereas, P application should be restricted to February as single dose for better nutrients uptake. The findings of this experiment indicate the potential of same dose of N, P, and K to increase the productivity by reducing pre-harvest fruit drop, increasing number of harvested fruits and yield if N & K are splited in three applications, *i.e.* February, April and July in Kinnow orchards. It is also suggested that N, P, K application frequency should be adjusted based on growth/ phenological stages.

Table 5. Effect of split application of nutrient doses on leaf nutrients composition in Kinnow (pooled mean).

Treatment	N (%)	P (%)	K (%)	Zn (ppm)
T_1	2.43	0.138	0.705	31.18
T_2	2.55	0.128	0.576	29.87
T_3	2.43	0.119	0.644	30.56
T_4	2.33	0.126	0.522	28.64
CD at 5%	0.20	NS	0.119	NS

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