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Effect of Potash Application on Yield and Quality of Kinnow Mandarin in Sandy Loam Soils of South Western Zone in Haryana, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation was carried out at CCS HAU, Hisar (Haryana) during 2017-2021 on sandy loam soils to investigate the effect of soil and foliar applied potassium on Kinnow productivity and quality. There were five treatments *viz* T_1- 0.0g MOP plant^{-1} (control), T_2- soil application of 175g MOP plant^{-1} (RDK), T_3- soil application of 250.0g MOP plant^{-1}, T_4- soil application of 325.0g MOP plant^{-1} and T_5- soil application of 175g MOP plant^{-1} (RDK) followed by foliar application of KNO_3@ 2.0% in the end of May June and July laid out in RCBD with four replications. The data showed that treatment with soil application of 325.0g MOP plant^{-1} produced highest yield and yield parameters (average fruit weight, reduces fruit drop) followed by soil application of 175.0g MOP plant^{-1} + foliar sprays of KNO_3@ 2.0% in the end of May, June and July with leaf N/K ratio of 2.18-2.27 over control and recommended dose of K. The later treatments also markedly improved the quality in respect of TSS/acid ratio and ascorbic acid content without influencing the juice and peel thickness. Over all, either soil application of 325.0g MOP plant^{-1} or soil application of 175.0g MOP

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plant^{-1} + foliar sprays of KNO_3@ 2.0% in the end of May, June and July along with recommended dose of N and P is suggested to improve the productivity and fruit quality in Kinnow in sandy loam soils of south western zone in Haryana.

Keywords: Citrus, nutrients; soil & foliar application; physico chemical quality; leaf nutrients content.

1. INTRODUCTION

Citrus is an economically important fruit crops of India. Among citrus fruits mandarin comprises the fruits group that is more preferred since they can be easily peeled in fresh consumption. Kinnow, a mandarin hybrid, suitable for both transportation and storage with very sweet and flavourful nature and high appearance to consumers is gaining importance in citrus growing areas and dominates in the north western state like Punjab, Haryana, Delhi, Rajasthan and H.P. In Haryana states it occupies more than 40% of the total fruit area and having great potential for export to gulf countries. However, Kinnow production also suffers from low productivity with poor plant health and varying fruit external and internal quality with variable sizes of fruits which dramatically reduces the profitability of the produce. The fact that consumers' demand for large fruit leads to an increase in price and yield as described by Guardiola and Garcia-Luis [1]. Therefore, a great need to develop effective approaches to improve citrus yield and quality.

All the living plants require 17 minerals nutrients for optimal function and growth [2,3]. Potassium regulates the osmotic potential of plant cell and activates enzymes that are involved in respiration and photosynthesis [2]. When K is deficient in citrus trees, the rates of photosynthesis reduces and results in a negative effect of fruit set, yield and quality [4]. Potassium content does not usually affect tree growth over a wide range of variation, unless it falls below 0.4% [5]. Since yield is positively correlated with tree size it is essential to have adequate content of K in the tree. The K content in the leaves decreases throughout the season and fruit load can enhances this decrease as a result of K uptake by the fruits. Alternate bearing can change the K contents of various organs [6] and K imbalance between years can increase the fluctuation. The juice is a strong sink for K, which occur there mainly in the form of soluble potash salts of organic acids. Potassium is most important for external aspect of fruit quality. Low level of potassium results in small fruits which are rejected by fresh and export market in spite of thin rind and good colour [7]. Citrus trees generally do not show visible deficiency symptoms across a wide range of K status in leaves. However, fruit quality is quite sensitive to varying level of K availability. Therefore, it is essential to apply potassium fertilizers to replace the K removal by the fruits, to improve fruit quality and to maintain soil productivity. Potassium fertilizer application increased citrus fruit partial quality parameters [8,9].

Fruit yield and quality can also be affected inconsistently by different form of K and its application. Therefore, the application methods and form of K fertilizers should be further explored according to weather conditions, variety, consumption, and demand in practice. It has been found that foliar application of K after flowering increased fruit size and yield of citrus [10,11]. On the other hand, unscientific fertilization, low fruits external and internal quality is the major obstacle to the development of the citrus industry in India. Hence a balanced nutrition has been paid attention in agricultural areas over the years and will continue to do so in the year ahead not because of rising concern about newly emerging problems related to soils health, but because a growing emphasis on high quality production. In the present investigation the Kinnow orchard was selected which is bearing variable sizes fruits and having the soil available K 500-560kg/ha during the year 2002 and presently 357 kg/ha even with the supplement of 175g MOP/plant annually. This shows that K application was not supplemented as per the removal by citrus plants. Hence, the study was conducted with the objective to investigate the effect of foliar and soil application of K doses on yield, quality and leaf nutrients content in Kinnow mandarin.

2. MATERIALS AND METHODS

2.1 Study Area

The present investigation was carried out in the experimental orchard of the department of Horticulture, CCSHAU, Hisar during the successive four years (2018-19 to 2021-22) on

seven years old Kinnow plants spaced at 6 x 6m and budded on rough lemon rootstock. The climate of the region is subtropical semi - arid irrigated with average rainfall of 450mm annually and most of the rainfall takes place during monsoon season (July to September) with occasional rainfall during winter season due to western disturbances. The summers and winter are extremes with maximum temperature about 45^0C during summer and occasional frost during winter season. The soil of the experimental site was fertile and rich in potash content (Table-1).

Table 1. Initial soil properties of the experimental orchards

Properties (0-30cm depth)	Values
Texture	Sandy loam
pH	7.92
EC (ds m^{-1})	0.37
OC (g kg^{-1} soil)	3.2
Available Nitrogen (Kg ha^{-1})	125.50
Available Phosphorus (Kg ha^{-1})	11.30
Available Potassium (Kg ha^{-1})	357.00

2.2 Treatment Detail

The experiment was laid out in randomize complete block design (RCBD) with four replications (one plant per replication) by taking uniform plants having similar shape, size and health and kept under uniform cultural practices as per package of practices for fruit crops, CCSHAU, Hisar. There were five treatments comprising of T_1: 0.0g MOP $plant^{-1}$ *i.e.*0.0g K $plant^{-1}$(control); T_2: Soil application of 175.0g MOP $plant^{-1}$ *i.e.*105.0g K $plant^{-1}$ (RDK); T_3: Soil application of 250.0g MOP $plant^{-1}$ *i.e.*150.0g K $plant^{-1}$; T_4: Soil application of 325.0g MOP $plant^{-1}$ *i.e.*195.0g K $plant^{-1}$ and T_5: Soil application of 175.0g MOP $plant^{-1}$ *i.e.*105.0g K $plant^{-1}$ and foliar application of KNO_3 @ 2% at the end of May, June and July. Soil application of uniform doses (800g N $plant^{-1}$) and P_2O_5 @ 450g $plant^{-1}$or 195.0g P was given to all the plants under study as per farmer practices. Full doses of P and K were applied in the month of January and N was applied in two splits i.e. half dose in January and remaining half in April. Nitrogen was applied in the form of urea and phosphorus as DAP.

2.3 Data Collection and Analysis

Data for yield was collected in the last week of December every year. Pre harvest fruit drop was measured by counting the number of dropped fruit per plant from September till harvesting and expressed as percent fruit drop per replication. Similarly, number of fruits per plant were counted and expressed as number of fruits/plant and averaged. Yield (Kg $plant^{-1}$) was calculated by multiplying the number of fruits for each plant to the average fruit weight of that respective plant. 12 representative fruits per plant from all direction and position were picked, and average fruit weight was taken by weighing on electronic balance and averaged for each replication. Six fruits selected from 12 fruits/ plant for measuring fruit weight, were further used for analysing quality parameters. Peel thickness was measured at the equator of fruit with the help of vernier calliper and averaged. Juice of the fruits was extracted with the help of citrus juice extractor and expressed as percentage on weight basis. Similarly, TSS content was measured with the help of hand refractometer. Acidity and ascorbic acid were measured with the methods of AOAC [12].

For estimating the leaf nutrients content about 5-7 months old leaves were collected from plants at chest height from non - fruiting shoot in the mid of September and prepared for estimation of N,P,K contents by cleaning with cotton and washing with 0.1% HCl solution and consequently with distilled water twice and dried in the oven at 68^0C till constant weight. The well ground samples were digested with diacid H_2SO_4: $HClO_4$ (4:1). Leaf nitrogen content was estimated with Nessler's reagent method, phosphorus with Vandomolybdo yellow colour method as described by Jackson [13]. Potassium content was estimated by Flame photometer as described by Piper [14].

2.4 Statistical Analysis

The recorded data for four year was pooled, compiled and subjected to statistical analysis by using OPSTAT software [15].

3. RESULTS AND DISCUSSION

3.1 Yield and Yield Parameters

All yield parameters influenced significantly with various treatments (Table-2). A clear trend was observed in increasing number of fruits/ plant, yield (kg/plant) average fruit weight and decrease in pre harvest fruit drop as result of potash application. The highest yield in respect of number of fruits/plant (461.3), fruit yield (71.47kg $plant^{-1}$) was found in treatment T_4 which was at

par with treatment T_5 (68.48kg plant^{-1}) and significantly superior to T_3, T_2 and T_1. The minimum yield (316.19 fruits plant^{-1}) and (43.79 kg plant^{-1}) were recorded in treatment T_1 which was at par with T_2 (RDF), whereas, T_3 was found significantly superior to T_1, and at par with T_5. Pre harvest fruit drop reduced significantly with application of K fertilizer. However, the minimum fruit drop 16.29 % was recorded in treatment T_4 followed by T_5, T_3 and T_2. Maximum fruit drop 29.85% was found in T_1 (control) followed by T_2 (22.06%). All treatments increased the average fruit weight significantly over T_1 (control). However, the maximum (154.98g) was recorded in treatment T_4 closely followed by T_3 (154.37g) and T_5 (150.04g). Soil K application treatment T_4, in general resulted in 63.21% and 41.28% higher yield over control (T_1) and T_2 (RDF). Similarly 45.13% and 26.15% lower fruit drop and 14.69% and 6.56% more fruit weight over control (T_1) and T_2 (RDF). Higher yield and yield parameters in potassium treated trees may be the result of high vigour/ canopy volume due to higher vital physiological processes and ultimately more canopy volume bearing more number of fruits per tree that were retained up to maturity and improved fruit weight and finally the yield. The importance of tree vigour in light interception and its correlation with the synthesis of photosynthesis and finally with yield have been well documented by Duncan [16]. Kumar et al. [9] observed relationship between canopy volume and fruit yield and further, fruit yield and physiological processes and leaf chlorophyll content in Kinnow with potassium application.

3.2 Quality Parameters

Fruit quality in respect of juice content, peel thickness was non - significant, whereas, TSS, acidity, TSS: acidity, ascorbic acid differed significantly with soil and foliar application of K (Table-3). Juice content increased slightly with every increase in soil application and foliar spray of K, but could not reach to the level of significance. Maximum juice content (42.56%) was noticed in treatment T_4 and minimum (41.50%) in T_1 (control). Peel thickness varies between 3.18 - 3.47mm and in general there was little increase in peel thickness with soil application of K. However, the minimum value 3.18mm was noticed in treatment T_2 and maximum (3.47mm) in treatment T_4. There was gradual increase in TSS content with the increase in doses of soil potassium application. Higher TSS content was noted in T_4 (9.61%), statistically at par with T_5 (9.52%), T_3 (9.32%) and significant over T_2 and T_1. Significantly lower value was observed in T_1 (8.89%). All treatments were found significantly effective in reducing the acidity content over control, whereas, foliar substitution of K application in T_5 was significantly most effective in reducing the acidity over T_2 (RDF) and T_4 and all the soil K application treatments T_2, T_3 and T_4 were at par with each other. Maximum acidity (1.16%) was recorded in T_1 and Minimum (0.98%) in T_5. The TSS: acidity ratio of juice was noted highest in treatment T_5 (9.70) which were statistically at par with T_3 and T_4 and lowest value (7.90%) was noticed in control (T_1). In all treatments where K was applied as soil were at par. Regarding ascorbic acid content there was gradual increase in ascorbic acid with the application of K. However, the maximum (27.52mg/100ml of juice) was noticed in treatment T_5 which was significantly higher over other treatments. All the soil applied potassium, T_2, T_3, T_4 were also showed statistically higher ascorbic acid over control. T_3 and T_4 were also at par with each other.

It is therefore clear that soil K application markedly improved the fruit quality of Kinnow in respect of higher TSS, TSS: acid ratio, ascorbic acid and reducing acidity over control, whereas, foliar applied K most influenced the quality parameters. These results may be attributed to higher production of carbohydrates and their translocation to fruits in K treated fruits as reported by Alye et al [11]. Ashraf et al. [17]; Marschner [18]; Desai et al. [19] also reported higher TSS, TSS: acid ratio due to potassium fertilization in Kinnow over non potassium fertilization. Further, ascorbic acid content in fruit is a production of enzymatically governed oxidation – reduction conversions. Several such enzymes responsible for these redox reaction used potash for their activation as suggested by Fench et al. [20]. Hence ascorbic acid content was more in K treated fruit plants over control. In the present investigation the improved fruit quality may therefore be assumed as the result of K application Tohidloo et al. [21].

3.3 Leaf Macro Nutrients

Leaf N and P content could not be affected significantly with various treatments (Table-4). However, N and P contents in general improved slightly and this may be due to better vigour and health of the plant with K application and hence more uptake of N and P assumed to be increased. Leaf K content increased significantly

Table 2. Effect of soil and foliar application of potassium on fruit drop and yield of kinnow mandarin (pooled mean data of four years)

Treatments	No. of fruits plant^{-1}	Av. Fruit wt. (g)	Pre harvest fruit drop (%)	Yield (kg plant^{-1})
T_1: 0.0 g MOP plant^{-1} (control)	316.19	135.13	29.85	43.79
T_2: 175.0 g MOP plant^{-1} (RDK)*	355.75	145.44	22.06	50.55
T_3: 250.0 g MOP plant^{-1}	387.69	154.37	18.86	59.84
T_4: 325.0 g MOP plant^{-1}	461.37	154.98	16.29	71.47
T_5: RDK + foliar application of KNO_3 @ 2% at the end of May, June and July	433.53	150.04	17.46	65.48
C.D. (p=0.05%)	44.93	8.70	2.73	11.13

**RDK- Recommended dose of Potash*

Tables 3. Effect of soil and foliar application of potassium on fruit quality of kinnow mandarin (pooled mean data of four years)

Treatments	Juice content (%)	Peel thickness (mm)	TSS (%)	Acidity (%)	TSS/ acidity	Ascorbic acid (mg/100ml of juice)
T_1: 0.0g MOP plant^{-1} (control)	41.50	3.25	8.89	1.16	7.90	23.24
T_2: 175.0 g MOP plant^{-1} (RDK)*	41.97	3.18	9.13	1.05	8.94	24.46
T_3: 250.0 g MOP plant^{-1}	42.35	3.32	9.32	1.00	9.43	24.67
T_4: 325.0 g MOP plant^{-1}	42.56	3.47	9.61	1.06	9.19	25.84
T_5: RDK + foliar application of KNO_3 @ 2% at the end of May, June and July	42.11	3.21	9.51	0.98	9.70	27.52
C.D. (p=0.05%)	NS	NS	0.43	0.06	0.62	1.13

***** *RDK- Recommended dose of Potash*

Table 4. Effect of soil and foliar application of potassium on leaf nutrients content of kinnow mandarin (pooled mean data of four years)

Treatments	N (%)	P (%)	K (%)	N/K
T_1: 0.0g MOP plant^{-1} (control)	2.32	0.12	0.78	2.96
T_2 175.0 g MOP plant^{-1} (RDK)*	2.40	0.13	0.89	2.70
T_3: 250.0 g MOP plant^{-1}	2.43	0.14	1.07	2.27
T_4: 325.0 g MOP plant^{-1}	2.43	0.14	1.11	2.18
T_5: RDK + foliar application of KNO_3 @ 2% at the end of May, June and July	2.42	0.14	1.06	2.24
CD (p=0.05%)	NS	NS	0.10	0.14

** RDK- Recommended dose of Potash*

with application of soil and foliar potash application over control. However, the maximum K content (1.11%) was estimated in treatment T_4 which was at par with T_5 and significant over control and T_2 (RDF). The lowest value 0.78% was estimated in control (T_1). Leaf N/K ratio decreased significantly in various treatments over control. However, the maximum N/K ratio (2.96) was calculated in control (T_1) and minimum (2.18) in T_4 which was at par with T_5 and T_3 which were further significantly lower to T_2 (RDF). Hence, it may be inferred that the appropriate N/K ratio in Kinnow should be in the range of 2.18-2.27 for optimum yield and good quality fruits.

In the present study importance of K fertilization in Kinnow mandarin was recognised in south western irrigated ecosystem of Haryana which is rated high in available K. It was hypothesized that a temporary K deficiency may be formed due to higher evapo-transpirational rate of the plant during peak summer which further coincides with major fruit and root growth stages in Kinnow. Consequently, the uptake of K from available pool may exceed the rate of its replenishment

from the fixed pool in the soil. This may influence K uptake and subsequently, the vital physio-biochemical processes and finally yield, quality and health of Kinnow plant as evident from the present investigation due to low leaf K content and high N/K ratio in control T_1 and T_2 (RDF).

4. CONCLUSION

In citrus orchard having sandy loam texture, pH (7.92), EC (0.37ds m^{-1}), OC (3.2g kg^{-1} soil), available N (125.50 kg ha^{-1}), available P (11.30 kg ha^{-1}) and available K (357.00 kg ha^{-1}), soil application of 325.0g MOP $plant^{-1}$ showed highest fruit yield (71.47kg $plant^{-1}$) followed by soil application of 175.0g MOP $plant^{-1}$ + foliar sprays of KNO_3@ 2.0% at the end of May, June and July (65.48kg $plant^{-1}$) and soil application of 250.0g MOP $plant^{-1}$ (60.36 kg $plant^{-1}$) over control (43.79kg $plant^{-1}$) and RDF (50.55kg $plant^{-1}$) with increased fruit weight without much influencing the fruit quality in respect of juice content, peel thickness. However, significantly lowest acidity 0.98% and highest TSS: acidity ratio 9.70 was observed with soil application of 175.0g MOP $plant^{-1}$ + foliar application of KNO_3@ 2.0% at the end of May, June and July.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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