

Dose optimization of Potassium (K^+) for yield and quality increment of strawberry (*Frageria* × *ananassa* Dutch)

Abstract

The importance of Potassium (K^+) in plants cannot be circumvented and its role in fruit and taste development is no longer an enigma. However its proper application time and amount is greatly varies in different plants. As strawberry fruit is new in the fruit industry of Pakistan therefore the growers are still unaware of the proper dose needed to obtain better yield. To achieve this goal the present ~~research~~ study was designed to optimize the proper dose of Potash (K^+) for strawberry under the agro-climatic conditions of Peshawar-Pakistan. Four different doses (50, 60, 70 and 80 $kg\ ha^{-1}$) were applied to strawberry (*Frageria* × *ananassa* Dutch) Cultivar Chandler. The results obtained (for various yield and quality related attributes) were then compared with that of untreated control plants. The results ~~determined~~, revealed that all parameters were significantly influenced by different levels of Potash. However days to flowering, fruit set and fruitmaturity, number of fruits and runners, fruit size and total yield along with fruit acidity, ascorbic acid, TSS and pH were efficiently influenced by Potassium applied at 70 $kg\ ha^{-1}$. Finally we were able to conclude that Potassium should be applied at 70 $kg\ ha^{-1}$ in order to get good yield and to improve the quality of strawberry fruits under the agro-climatic conditions of Peshawar.

Key words: Ascorbic acid, Cultivar Chandler, Strawberry fruit, Potassium, TSS.

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2 1. INTRODUCTION

3 Strawberry (*Fragaria × ananassa*) has been get much popularity among growers due to several
 4 reasons, despite the fact it introduced since 1960s (Sharma and Sharma 2004a), however in recent
 5 years it is a well known fruit crop for its redolent and savour characteristics (Sharma . Cv. 004b).
 6 Strawberry cultivation prefers open field conditions (Wojcik and Marusz 2011), cv. Chandler (Kaur
 7 et al. 2003) and Elsanta (Wojcik and Marusz 2011) is the most commonly cultivated variety in India
 8 and Europe respectively due to their high potential yield and good fruit quality. In Pakistan, its
 9 production is confined to some specific areas of Khyber Pakhtunkhwa and Punjab, however its
 10 cultivation for commercial purpose is gaining importance among the growers as a cash crop. It is
 11 grown at lower altitudes in Khyber Pakhtunkhwa, from November to June in areas of Swat,
 12 Abbottabad, Mansehra, Haripur, Mardan, Peshawar, Charsadda, while in some areas of Punjab like
 13 Gujrat, Sialkot, Jhelum and Chakwal (Afridi et al., 2009; Dad, 2011). The a . There are of
 14 Peshawar region are subtropical (Bakht et al., 2006) and often receive less rainfall therefore most of
 15 the crops cultivated here remain under water stress which adversely affect its potential yield and
 16 quality. Strawberry being a high value cash crop and highly perishable (Amin, 2006), much attention
 17 should be paid to standard cultivation practices along with proper and on time nutrition of the plants.
 18 As potassium has a well known functional importance in water regulation and uptake in crops under
 19 water stress consequently making the crop resistive d water stress as it facilitates the . for
 20 pressure of guard cell during stomata movements (Marshner, 1995; Shukla et al., 2009) The yield
 21 and quality of fruit crops is greatly dependent on the proper supply of essential plant nutrients, the
 22 yield and quality of fruit crop may deteriorates in case of nutritional imbalance (Kumar Yadav et al.
 23 2009). Plants depend upon the regulation of potassium on opening and closing of stomata. It is also
 24 related to the transport of sugars and other nutrients in xylem (Sczzerba et al., 2008). Potassium
 25 helps in activation of several bio chemical processes like photosynthesis, formation of starch,
 26 protein synthesis, sugar and regulation of water balance. Potassium also activates enzymes which
 27 act as catalyst in several metabolic reactions. There are more than 60 enzymes discovered which
 28 needs potassium for activation (Akhtar et al., 2003). Sulfate of potash (SOP) as a source of
 29 Potassium at 60 kg K₂O ha⁻¹ increases, fruit weight, fruit length, number of fruits plant⁻¹ and fruit
 30 yield. It was also observed that SOP significantly influenced the quality characteristic of chili. Plants
 31 treated with Potassium at 60 kg ha⁻¹ also noted to have minimum disease occurrence in contrast to
 32 other treatment combinations therefore the proper application dose is very critical (Ananthi et al.,
 33 2004). Strawberry is newly introduced crop and its average yield ha⁻¹ is very low in agro-climatic
 34 conditions of Peshawar. There are various limiting factors which are responsible for low yield i.e.
 35 lack of modern technology, lack of research work and technical guidance and lack of economic
 36 value among the growers (Jskani, 2014). There is lack of awareness about the recommended dose
 37 of potassium for obtaining good yield, so the present study has been designed to optimize the most
 38 efficient dose of Potassium (K⁺), as it is often neglected or given less importance as compared to
 39 (NP) by growers despite of its very important functions within the plant body.

40

2. MATERIAL AND METHODS

2.1 Experimental Site and Plant Material

The research was conducted at Newly Developed Farm (NDF) at Horticulture section, The University of Agriculture Peshawar, Pakistan during 2011-12. The runners of Strawberry were brought from Agricultural Research Institute Mingora, Swat. These Strawberry runners were planted in the month of November, 2011.

2.2 Soil Analysis

The soil samples collected from the experimental site from various depths were analyzed for Nutrients, AB-DTPA extractable K, soil organic matter, Electro conductivity and pH under the standard methods applied by Soltanpour and Schwab (1977) and McLean(1982). The obtained values against different soil properties are presented in Table 1.

2.3. Fertilizer Application and Experimental Design

Sulfate of potash (SOP) was used as a source of Potassium (K), (SSP) as Phosphorus (P) and Urea as Nitrogen (N). K was not applied in control treatment while P and N were applied at the rate of 90 and 100 kg ha⁻¹ respectively in all treatments including control. Four different doses (50, 60, 70 and 80 kg ha⁻¹) of Potash (K⁺) were tested. The experiment was laid out in simple Randomized Complete Block Design (RCBD) for the above mentioned levels of potassium. There were five treatments in each replication including control. The experimental field was divided in 15 plots having a size of 3x2 m². There were 05 rows in each plot having 05 plants on each row. Plant and row to row distance were kept 30 cm and 60 cm in each experiment respectively. Sawdust was used as mulch for mulching to avoid chilling temperature and to obtain clean fruits at the time of harvest.

The distance between plant

2.4. Parameters studied

2.4.1. Yield related attributes

Days to flowering (DF), days to fruit set (DFS), days to fruit maturity (DFM), number of fruits plant⁻¹ (NF), fruit size (FS (cm³)), number of runners plant⁻¹ (NR) and total fruit yield (TY (tonnes ha⁻¹)), were studied and the results were statistically analyzed.

2.3.2 Quality related attributes

Total soluble solids (Brix⁰), percent acidity (%), ascorbic acid (mg ml⁻¹) and fruit juice pH were found through the standard methods developed by (A. O. A. C. 1984 and 1990) and the obtained values were then analyzed by applying the following statistical procedure.

pH of fruit juice

2.5. Statistical analysis

The collected data for different parameters was subjected to analysis of variance (ANOVA) to find the difference between different treatments. In case where the differences were significant the

mean was further assist for differentiation through least significant difference (LSD) test. Statistical software(Statistix8.1), was applied for computing both ANOVA and LSD.

3 RESULTS AND DISCUSSION

3.1 Yield related attributes

3.1.1. Days to flowering

The ~~data noted for total number of~~ days to flowering in strawberry is shown in Table 1. The analysis of data recorded determines that different levels of Potassium had a significant effect (P=0.05) on the days to flowering, the mean values revealed that potash levels were significantly different from untreated plants but non-significant with each other. The highest number of days (109.14) to flowering was noted in control plants, while the lowest number of days (102.39) to flowering recorded in plants treated with Potassium at 80 kg ha⁻¹.

Flowering is a vital role in plants for the processes of pollination which is essential for fruit growth and development. Early flowering induced in different potash levels might be due to the applied potash because K induces early growth, activate enzymes and the efficiency of other applied nutrients (El-Nemr *et al.*, 2012). These results were also in correspondence with hane *et al.*, (1992) who observed significant effect due to potash.

Table 1: Soil analysis for pH, EC, Soil organic matter, Lime and AB-DTPA extractable K determined for various soil depths.

Property	Unit	0-15 cm	15-30 cm	30-45 cm	45-60 cm
pH (1:5)	-	7.71	7.92	7.94	7.87
EC (1:5)	dsm ⁻¹	0.21	0.20	0.15	0.14
Soilorganic matter	%	2.04	1.92	1.90	1.78
Lime	%	20.65	19.23	17.61	16.99

AB-DTPA mg kg⁻¹ 6.41 6.18 5.47 5.46
Extractable K

3.1.2. Days to fruit set

The data recorded for days to fruit set in strawberry plant is mentioned in Table 2. Data analysis shows that the days to fruit set in strawberries were significantly affected (P=0.05) by different levels of Potassium.

The data of the table shows that the highest days for fruit set (6.84) were observed in control plot, while the lowest days to fruit set (6.53) were observed in plants treated with 80 kg Potassium ha⁻¹. Potassium applications gave reasonable good response for increasing number of fruits plant⁻¹. The number of fruits plant⁻¹ can be related with the increase and decrease of number of flowers. Highest fruit yield plant⁻¹ and highest number of fruits plant⁻¹ may be due to maximum uptake of N, P and K potassium helps in nutrient uptake. This might have increased the chlorophyll content in foliage resulting in improved synthesis of carbohydrates and build up of more new cells (Maynard, 1962). These results were in relation to Varis *et al.*, (1985) accordingly potassium enhances vigorous tomato growth, early flowering and setting of fruits, however its deficiency will causes slow stunted growth, number of fruits and reduction in yield.

Table 2: Yield and yield related attributes as affected by different levels of Potassium (K).

Treatments	DF	DFS	DFM	NF	FS (cm ³)	NR	TY (tonnes ha ⁻¹)
Control	109.14 ^a	6.84 ^a	28.28 ^a	4.55 ^d	4.21 ^c	11.06	2.18 ^c
50 kg K ha ⁻¹	105.95 ^b	6.65 ^b	23.83 ^b	6.49 ^c	5.09 ^{bc}	11.67	3.25 ^b
60 kg K ha ⁻¹	105.29 ^b	6.58 ^{bc}	23.76 ^b	7.37 ^b	5.29 ^{bc}	12.33	3.42 ^b
70 kg K ha ⁻¹	105.11 ^b	6.54 ^{bc}	23.13 ^b	8.30 ^a	5.94 ^b	11.39	5.07 ^a
80 kg K ha ⁻¹	104.78 ^b	6.53 ^c	23.16 ^b	7.85 ^{ab}	7.63 ^a	12.34	4.48 ^a
Significance	*	*	*	*	*	NS	*
LSD	1.80	0.11	0.56	2.53	1.60	3.34	0.71

*Significance at α0.05, NS= non-significant

Values sharing same letters are non-significant with each other while significantly different from those values which have different letters.

3.1.3. Days to fruit maturity

The data recorded for days to fruit maturity of strawberry plants is mentioned in Table 2. Data analysis indicates that, the days to fruit maturity of strawberry plants were significantly effected (P= 0.05) by all Potassium levels.

The mean values of data shows that potash levels have significant difference to control plants but were non-significant with each other. The highest number of days to fruit maturity of strawberry plants (28.28) was observed in control plants and the lowest number of days (23.13) was observed in plants treated with 70 kg potassium ha⁻¹. These results could be supported as the percentage of unevenly ripened, irregularly shaped and hollow tomato fruits decreased with increased potassium dose (Winsor, 1973). While the effects of K on maturity in different vegetable and fruits is variable, but its application in Maiz speeds up silking, increases yield and the lack of K in soybean delays its maturity (Better crops Vol.82, No.3, 1998).

3.1.4. Number of fruits plant⁻¹

The data recorded for number of fruits in strawberry plant is mentioned in Table 2. Data analysis shows that the number of fruits were significantly effected (P=0.05) by different levels of potash.

The mean values show that the highest numbers of fruits (8.30) were observed in the plants that were treated with 70 kg Potassium ha⁻¹, while the lowest numbers of fruits (4.55) were observed in control plot.

Potassium applications gave reasonably good response by increasing number of fruits plant⁻¹. The number of fruits plant⁻¹ can be related with the increase and decrease of number of flowers. Highest fruit yield plant⁻¹ and highest number of fruits plant⁻¹ may be due to maximum uptake of N, P and K as potassium helps in nutrient uptake. This might have increased the chlorophyll content in producing resulting in improved synthesis of carbohydrates and build up of more new cells (Maynard, 1962). The same results are evident in the study of (Ananthi et al., 2004) which stated that, among different combinations of potash, application of 60 kg K₂O ha⁻¹ as SOP was superior in producing more number of fruits plant⁻¹ in chilies. Medhi et al. (1990) found that the application of potash maximized the number of fruits plant⁻¹ in Chili.

3.1.5. Fruit size (cm³)

The data recorded for fruit size of strawberry plants is shown in Table 2. The Analysis of Variance shows that the fruit size of strawberry plants were significantly effected (P=0.05) by different potash levels. The mean values reveals that the highest fruit size (7.63 cm³) was observed in the plants treated with potassium at 80 kg ha⁻¹, while the smallest fruit size (4.21 cm³) was recorded in control plot.

These differences might be correlate as, when carbon dioxide is converted into sugars during photosynthesis, the sugars have to be transported to organs of the plant where it will store or used for growth and development. The plants transportation system requires energy in the form of (ATP) which needs potassium for its synthesis. The transportation of sugar from leaves to fruit is greatly reduced in potassium deficient plants (Malik, 1994). These results were similar to the findings of (Yagmur et al., 2004) They stated that potassium has a crucial role in the production of the large yields/combined with fruit quality. Potassium stimulates plant growth, fruit size, fruit aroma and taste by enhancing the production of sugars and acids in tomato.

Yagmur et al. (2004).

3.1.6. *Number of runners*

The data noted for Number of runners of strawberry plant is shown in Table 2. Data analysis shows that the number of runners plant⁻¹ ~~was~~ non-significantly influenced by different levels of potassium.

However the mean values of data shows that the highest number of runners (12.34) were observed in the plants treated with 90 kg Potassium ha⁻¹, while the lowest number of runners (11.06) was noted in untreated plants. The non-significant effect on number of runners of strawberry plant might be due to the same genetic makeup of plants. However the number of tillers in black barley increased significantly due to K⁺ accumulative ability of this cultivar (Al-Basal and Yasseen, 2009).

3.1.7. *Total fruit yield ha⁻¹*

The data recorded for total fruit yield of strawberry is mentioned in Table 2. Data analysis shows that the total fruit yield of strawberry plants ~~were~~ significantly effected (P=0.05) by different levels of potassium. The mean values reveals that, the highest total fruit yield (5.07 tons ha⁻¹) ~~was~~ observed in plants treated with potassium at 70 kg ha⁻¹, while the lowest yield (2.18 tons ha⁻¹) ~~was~~ recorded in control treatment.

The increase or decrease in yield ~~is~~ entirely depends upon ~~t~~ increase or decrease on total number of fruits plant⁻¹. According to ~~(Singh and Verma, 1991)~~ the treatment which gave more fruits of heavy weight gave more yield and vice versa. The abundant cation present in phloem sap is potassium (almost 80% of the total ~~cat ions~~) helping in the productions of sugar and transporting it through the phloem into sink organs (Cakmak, 2005). Potassium have crucial role in photosynthesis and metabolism of carbohydrates. An optimum potassium supply ~~results in~~ better sugar content of sink organs (Marschner, 1995). These results are in line with that of (Akhtar et al., 2010), that the ~~incr~~ of potassium causes a significant increase in tomato yield. While (El-Bassiony et al., 2010) stated that the highest potassium fertilizer rate gave tallest sweet pepper plants, branches plant⁻¹, the highest fresh and dry weight o leaves, highest number of leaves and highest total yield. The optimum dose of potassium also resulted a highest yield of tomato (Yagmur et al., 2004). A higher potassium in the nutrient solution resulted in increased yield of tomato fruits (El-Nemr et al., 2012).

3.2 *Influence of K⁺ on quality attributes*

3.2.1. *Ascorbic acid (mg ml⁻¹)*

The data recorded for ascorbic acid in strawberry fruit's juice is mentioned in Table 3. The Analysis of Variance indicates that, the ~~ascorbic acid content~~ was significantly affected by different potassium at (P=0.05) level of significance. The highest value for ascorbic acid concentration

(63.50) was determined in fruits which were treated with potassium at 70 kg ha⁻¹, while the lowest concentration (54.71) was recorded in fruits obtained from those plants which were kept control.

The gradual increase in potassium dose, resulted in higher yield but it decreases the concentration of vitamin C content in fruit and vice versa. This might be due to an increase in water absorption capacity by plants as well as in fruits (Mengel and Kirkby, 1987). These results were in correspondence with Yagmur et al., (2004) which concludes that the optimum dose of potassium 360 kg k₂O ha⁻¹ significantly increased the total yield, average fruit weight and acidity but decreased the ascorbic acid, total soluble solids and colour of fruit. While it nullify the results of El-Nemr *et al.*, (2012) that increasing potassium dose in the nutrient solution resulted an increase in vitamin C content of tomato fruits.

Table 3: Quality attributes as affected by different levels of Potassium (K).

Treatments	Ascorbic Acid (mg ml ⁻¹)	%Acidity	TSS (Brix ⁰)	pH
Control	54.71 ^c	0.57 ^c	6.30 ^b	2.27 ^b
50 kg K ha ⁻¹	58.35 ^b	0.61 ^{bc}	7.46 ^a	2.33 ^b
60 kg K ha ⁻¹	58.69 ^b	0.64 ^{abc}	7.70 ^a	2.33 ^b
70 kg K ha ⁻¹	63.50 ^a	0.73 ^a	7.73 ^a	2.36 ^{ab}
80 kg K ha ⁻¹	61.80 ^a	0.71 ^{ab}	8.00 ^a	2.46 ^a
Significance	*	*	*	*
LSD	2.85	0.10	0.63	0.11

* Significance at α0.05, NS= non-significant

Values sharing same letters are non-significant with each other while significantly different from those values which have different letters.

3.2.2. Percent Acidity

The data noted for percent acidity ^{is} mentioned in Table 3. The values mentioned in mean Table, indicates that percent Acidity was significantly effected (P=0.05) by different levels of potassium. With reference to Table 3, highest percent Acidity (0.73) was observed in fruits of that plants which were treated with potassium at 70 kg ha⁻¹, while the lowest percent Acidity (0.57) was recorded in control treatment.

Increase in percent acidity of fruits in treated plants indicates the correlation between potassium levels and percent acidity. These results can be supported as; when potassium is applied with higher dose it increases the titratable acidity (TA) and sugar content of tomato. The higher dose decreases the ratio between sugar content and TA. Hence a decrease in this ratio results better taste development in tomato fruit (Ni Wuzhong, 2002). Increasing potassium rate increases TA of

Yagmur et al. (2004). They found that

1 fruit juice (Winsor, 1973). Similar results were also obtained by Yagmur, 2004) that with increasing
2 potash doses TA also increases.

3 3.2.3. Total soluble solids (Brix⁰)

4 The data noted for total soluble solids of strawberry fruit juice is described in Table 3. The Analysis
5 of Variance shows that the total soluble solids were significantly effected (P=0.05) by different
6 levels of potassium. According to the mean values, the highest total soluble solids (8.00) for
7 strawberry fruit was noted in the fruits of those plants treated with potassium at 80 kg ha⁻¹, while
8 the lowest total soluble solids (6.30) were recorded in fruits of control plants.

9 Balibrea *et al.*, (2006) have stated that an increase in TSS of tomato fruits depends on a higher
10 sugar import and accumulation in fruits. Sofia, (2008) mentioned that, increase of TSS with the
11 higher potassium in the nutrient solution results the importance of potassium in enhancing qu (Matschner, 1995).
12 of tomato fruits. Potassium has a major role in photosynthesis and metabolism of carbohydrates.

13 An optimum potassium supply determines better sugar content of sink organs (Marschner, 1995).
14 these results were also in correspondence with Yagmur et al., (2004), that at optimum dose of
15 potassium 360 kg K₂O ha⁻¹ significantly increased the total yield, average fruit weight and acidity
16 but decreased ascorbic acid, total soluble solids and colour of fruit.

17 3.2.4. pH

18 Data pertaining pH of strawberry fruit juice is mentioned in Table 3. The mean values of shows
19 that the pH was significantly effected (P=0.05) by different potash levels. According to Table 2,
20 highest pH value (2.46) was observed in the fruits of those plants treated with potassium at 80 kg
21 ha⁻¹, while the lowest pH value (2.27) was noted in control plants.

22 The percent acidity and pH are correlated with each other. The lower percent acidity the lower will
23 be the pH and vice versa, but in case of potassium, pH increases due to the fact that potassium is
24 known as electro neutrality maintenance element of organic acids in tomato fruit, by increasing
25 potassium dose the plant water absorption capacity also increases so pH becomes higher (Fandi *et al.* 2010). These results were also in correspondence with El-Nemr *et al.*, (2012), that the higher
26 potassium in the nutrient solution resulted in increased contents of TSS, Vitamin C contents, TA
27 and juice pH in tomato fruits.

29 4. CONCLUSIONS

30 On the basis of results obtained, it could be infer that all potash (K⁺) levels significantly influenced
31 the yield and quality related parameters like days to flowering, fruit set and fruit maturity, number
32 of fruits and runners, fruit size and total yield, fruit acidity, ascorbic acid, TSS and pH especially the
33 potassium applied at 70 kgha⁻¹. Therefore we were able to conclude that potassium applied at the
34 rate of 70 kgha⁻¹ was most efficient to obtain good yield and to improve fruit quality of Strawberry
35 under the agro-climatic conditions of Peshawar-Pakistan.

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