Dose optimization of Potassium (K^+) for yield and quality increment f 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 kgha^{-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 fruit maturity, 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 kgha^{-1}. Finally we were able to conclude that Potassium should be applied at 70 kgha^{-1} in order to get good yield and to improve the quality of strawberry fruits under the agro-climatic conditions of Peshawar.

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

1. INTRODUCTION

Strawberry (Fragaria × ananassa Duch) did not get much popularity among growers due to several reasons, despite the fact it introduced since 1960s (Sharma and Sharma 2004a), however in recent years it is a well known fruit crop for its redolent and savour characteristics (Sharma et al. 2004b). Strawberry cultivation prefers open field conditions (Wojclk and Marlusz 2011), cv. Chandler (Kaur et al. 2003) and Elsanta (Wojclk and Marlusz 2011) is the most commonly cultivated variety in India and Europe respectively due to their high potential yield and good fruit quality. In Pakistan, its production is confined to some specific areas of Khyber Pakhtunkhwa and Punjab, however its cultivation for commercial purpose is gaining importance among the growers as a cash crop. It is grown at lower altitudes in Khyber Pakhtunkhwa, from November to June in areas of Swat, Abbottabad, Mansehra, Haripur, Mardan, Peshawar, Charsadda, while in some areas of Punjab like Gujrat, Sialkot, Jhelum and Chakwal (Afridi et al., 2009; Dad, 2011). The agro-climatic conditions of Peshawar region are subtropical (Bakht et al., 2006) and often receive less rainfall therefore most of the crops cultivated here remain under water stress which adversely affect its potential yield and quality. Strawberry being a high value cash crop and highly perishable (Amin, 2006), much attention should be paid to standard cultivation practices along with proper and on time nutrition of the plants. As potassium has a well known functional importance in water regulation and uptake in crops under water stress consequently making the crop resistive to water stress as it facilitates the turgor pressure of guard cell during stomata movements (Marshner, 1995; Shukla et al., 2009). The yield and quality of fruit crops is greatly dependent on the proper supply of essential plant nutrients, the yield and quality of fruit crop may deteriorates in case of nutritional imbalance (Kumar Yadav *et al.* 2009). Plants depend upon the regulation of potassium on opening and closing of stomata. It is also related to the transport of sugars and other nutrients in xylem (Sczzerba et al., 2008). Potassium helps in activation of several bio chemical processes like photosynthesis, formation of starch, protein synthesis, sugar and regulation of water balance. Potassium also activates enzymes which act as catalyst in several metabolic reactions. There are more than 60 enzymes discovered which needs potassium for activation (Akhtar et al., 2003). Sulfate of potash (SOP) as a source of Potassium at 60 kg K_2O ha^{-1} increases, fruit weight, fruit length, number of fruits $plant^{-1}$and fruit yield. It was also observed that SOP significantly influenced the quality characteristic of chili. Plants treated with Potassium at 60 kg ha^{-1} also noted to have minimum disease occurrence in contrast to other treatment combinations therefore the proper application dose is very critical (Ananthi et al., 2004). Strawberry is newly introduced crop and its average yield ha^{-1} is very low in agro-climatic conditions of Peshawar. There are various limiting factors which are responsible for low yield i.e. lack of modern technology, lack of research work and technical guidance and lack of economic value among the growers (Jskani, 2014). There is lack of awareness about the recommended dose of potassium for obtaining good yield, so the present study has been designed to optimize the most efficient dose of Potassium (K^+), as it is often neglected or given less importance as compared to (NP) by growers despite of its very important functions within the plant body.

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.

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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 kgha^{-1} respectively in all treatments including control. Four different doses (50, 60, 70 and 80 kgha^{-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 m^2. There were 05 rows in each plot having 05 plants on each row. Plant to 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.

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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 (cm^3)), 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 (Brix^0),percent acidity (%), ascorbic acid (mgml^{-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.

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}.

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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 Subhani *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 Extractable K	mg kg^{-1}	6.41	6.18	5.47	5.46

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 as 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 foliage 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 K_2O 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 (cm^3)

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 cm^3) was observed in the plants treated with potassium at 80 kg ha^{-1}, while the smallest fruit size (4.21 cm^3) 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.

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 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 the 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 resultsin better sugar content of sink organs (Marschner, 1995).These results are in line with that of (Akhtar et al., 2010), that the increase 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 increasein potassiumdose, 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 k_2O 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) thatincreasing potassium dose in the nutrient solution resulted an increasein 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

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

3.2.3. Total soluble solids (Brix^0)

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

Balibrea *et al.,* (2006) have stated that an increase in TSS of tomato fruits depends on a higher sugar import and accumulation in fruits. Sofia, (2008) mentioned that, increase of TSS with the higher potassium in the nutrient solution results the importance of potassium in enhancing quality of tomato fruits. Potassium has a major role in photosynthesis and metabolism of carbohydrates. An optimum potassium supply determines better sugar content of sink organs Marschner, (1995). these results were also in correspondence with Yagmur et al., (2004), that at optimum dose of potassium 360 kg K_2O ha^{-1} significantly increased the total yield, average fruit weight and acidity but decreased ascorbic acid, total soluble solids and colour of fruit.

3.2.4. pH

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

The percent acidity and pH are correlated with each other. The lower percent acidity the lower will be the pH and vice versa, but in case of potassium, pH increases due to the fact that potassium is known as electro neutrality maintenance element of organic acids in tomato fruit, by increasing 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 potassium in the nutrient solution resulted in increased contents of TSS, Vitamin C contents, TA and juice pH in tomato fruits.

4. CONCLUSIONS

On the basis of results obtained, it could be infer that all potash (K^+) levels significantly influenced the yield and quality related parameters like days to flowering, fruit set and fruit maturity, number of fruits and runners, fruit size and total yield, fruit acidity, ascorbic acid, TSS and pH especially the potassium applied at70 kgha^{-1}. Therefore we were able to conclude that potassium applied at the rate of 70 kgha^{-1}was most efficient to obtain good yield and to improve fruit quality of Strawberry under the agro-climatic conditions of Peshawar-Pakistan.

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