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Growth, Yield and Fruit Quality of Strawberry (*Frageria ananasa* Dutch) under Different Phosphorus Levels

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Abstract

Strawberry fruit takes less time for production and is easily multiplied. Fruiting is an exhaustive process and depletes nutrients especially phosphorus as it is highly immobile in the soil. An experiment was conducted in The University of Peshawar, Pakistan to evaluate different level of Phosphorous on growth, yield and fruit quality of Strawberry Cv Chandler. Results show that Phosphorus at 90 kg ha^{-1} significantly influenced the days to flowering (102.66) of strawberry plants while, at 80 kg ha^{-1} significantly affected days to fruit set (2.98), days to fruit maturity (20.05), Number of fruits (7.50) and Total fruit yield tons ha^{-1}(3.61). Fruit size (6.42 cm3) was significantly affected at 70 kg ha^{-1}. Similarly, Ascorbic acid (62.61), percent acidity (0.64) and Total soluble solids (7.83) were significantly affected by phosphorus at 60 kg ha^{-1}

Keywords

strawberry, phosphorous, ascorbic acid, yield

1. Introduction

Strawberry (Frageria ananassa Dutch) is a herbaceous perennial crop and is one of the most delicious and refreshing fruit. it is widely distributed in the world due to its genetic diversity and wide range of environmental adaptations. For a perishable fruit, it should be handled carefully during transportations (Amin, 1996). Karona and Tuft were identified as the best varieties for the cultivation due to their long shelf life (Ayaz et al., 1998). The strawberry culture is also suitable for the farmers having small holdings, as it fetches maximum economic returns. Nutritionally strawberries are considered to be a good low caloric and are a potential source of Vitamin C (64mg) and fiber. It is also considered as a good source of minerals, vitamins, iron and sodium. A mature fruit contains 89.9% water (USDA,

2011).

Strawberry is cultivated throughout the world including, USA, Japan, Mexico and Lebonan. In Pakistan, it is produced on a very small scale. Recently, a trend in boost of strawberry production is absorbed in certain areas of Khyber Pakhtunkhwa and Punjab and is gaining importance among growers of Khyber Pakhtunkhwa as a cash crop (Amin, 1996). It is grown at lower altitudes in Khyber Pakhtunkhwa. In Pakistan, the major growing areas are Swat, Abbottabad, Mansehra, Haripur, Mardan, Peshawar, Charsadda, Gujrat, Sialkot, Jhelum, Chakwal and Karachi (Dad, 2011). Due to its perishability fruit should be sold just after picking (Amin, 1996).

Among the fruits, it provides quickest return and can easily be multiplied. It is shallow rooted and thus requires frequent availability of nutrients for normal growth and yield. Tissue tests indicate that P levels in strawberry plants can be sufficient during most of the growing season yet still drop to low levels during harvest. This drop has occurred in fields with adequate to high soil-P indices (Campbell & Miner, 2000).

Phosphorus is a key element in plant structure as well as a catalyst in numerous biochemical reactions in plants. RNA and DNA are linked by phosphorus bonds and it is also an important component of DNA. It is also a major part of ATP, the energy unit of plants and has phosphorus in its structure which helps in seedling growth and maturation. Phosphorus helps in several growth factors like root development, increased stem length and stalk development, improved flower production and seed development. Plant treated with high dose of potassium responded well and gave significantly high yield (Ludilov and Ludilova, 1975).

Strawberry is newly introduced crop and its average yield ha-1 is very low in agri climatic conditions of Peshawar. There are different 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. There is no awareness about the recommended dose of phosphorous for the better crop. So, the aim of research word was to find the most suitable level of phosphorous for better yield and growth of strawberry.

2. Method

An experiment was conducted to study the effect on growth, yield and fruit quality of Strawberry under different Phosphorus levels at Newly Developed Farm (NDF) Horticulture section, The University of Agriculture Peshawar, Pakistan. The runners for Strawberry were brought from Agricultural Research Institute Mingora, Swat and were planted in the month of November. Single super phosphate (SSP) was used as a source of Phosphorus and a constant dose of urea was applied as a source for Nitrogen.

2.1 Phosphorus Levels

T1: Control

T2: Phosphorus at 60 kg ha-1

T3: Phosphorus at 70 kg ha-1

T4: Phosphorus at 80 kg ha-1

T5: Phosphorus at 90 kg ha-1

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. Saw dust was used as mulch for mulching to avoid chilling temperature and to obtain clean fruits at time of harvest.

2.2 Soil Analysis

The soil samples were analyzed for Nutrients, AB-DTPA extractable Phosphorus (Soltanpour & Schwab, 1977) soil texture, pH and Electro conductivity according to (McClean, 1982; Shrivastava et al., 1993).

Table 1. Organic Matter, Lime, Phosphorus, pH and EC of Soil at Different 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
Soil organic matter	%	2.04	1.92	1.90	1.78
Lime	%	20.65	19.23	17.61	16.99
AB-DTPA Extractable P	mg kg^{-1}	6.41	6.18	5.47	5.46

2.3 Days to Flowering, Fruit Set and Maturity

Days to flowering, fruit set and maturity were counted by taking five plants randomly, from the date of planting till appearance of first flower, and average was calculated.

2.4 Number of Fruits Plant^{-1}

Numbers of fruits plant^{-1} were counted by taking randomly five plants, and the average was calculated.

2.5 Fruit Size (cm^3)

The fruit size was measured with water displacement method by randomly taking five plants, and average was calculated.

2.6 Total Fruit Yield (Kg ha^{-1})

The strawberries were collected from randomly five plants from all the treatments and their weight were noted with electrical balance, and their average was calculated.

Yield ha^{-1} = yield $plot^{-1}$(kg) x 10000m^2 / Plot area (m^2)

2.7 Number of Runner's Plant^{-1}

Numbers of runner's plant-1 were calculated from randomly five plants, and average was calculated.

2.8 Total Soluble Solids ($Brix^0$)

Total soluble solids of strawberry juice from randomly five plants of all the treatments were determined by hand refractro-meter. Strawberry juice drop was placed on dry and clean prism of hand

rafractrometer and the reading was noted. For each and every treatment the prism was washed and cleaned with distilled water and dried with tissue paper (Kernco, instrument Co. Texas).

2.9 Percent Acidity (%)

Percent Acidity was determined by neutralization reaction of randomly five plants in each treatment in all replications as prescribed in (AOAC, 1990).

2.10 Ascorbic Acid ($mgml^{-1}$)

Ascorbic acid was determined through dye method by randomly five plants of all treatments in each replication by the standard method as reported in (AOAC, 1984).

2.11 Fruit Juice pH

Fruit juice pH of randomly selected plants was determined by pH meter. Before the use of pH meter the tip was washed with tap water and it automatically adjusts its pH to 7. Juice was extracted from randomly selected fruits through juicer and the sample of juice was taken in beaker for the pH determination purpose. The pH meter electrode on tip was diped in it and immediately pH reading was obtained on screen and was noted.

2.12 Statistical Procedure

The collected data for different parameters was subjected to analysis of variance (ANOVA) under Randomized complete block design and difference of means was obtained through least significant difference (LSD) test. Statistical software, Statistix, was applied for computing both ANOVA and LSD (Steel & Torrie, 1980).

3. Results and Discussion

3.1 Days to Flowering

According to Table 2, results show that the lowest number of days (102.66) to flowering was recorded in plants treated with Phosphorous at the rate of 90 kg ha^{-1}, While, the highest number of days (109.38) to flowering was noted in untreated plants. Earlier flowering in plants with the soil application of 90 kg phosphorous ha^{-1} might be due to the fact that phosphorous improves the earlier flower formation, earlier crop maturity and seed formation (Malik, 1994). It enhances development of reproductive parts, stimulates blooming and fruit setting (Khan et al., 2000). The present findings were in correspondence to (Gill et al., 1974) who stated that the number of days to flowering was lowest by optimum dose of phosphorous and flowering duration was increased in sweet pepper by increasing nitrogen. These results were also in correspondence to (Islam et al., 2009) when he studied the effect of phosphorus on micronutrients availability to plants.

Table 2. Effect of Phosphorus Levels on Days to Flowering, Fruit Set, Fruit Maturity and Number of Fruits on Strawberry

Phosphorus	Days to flowering	Days to fruit set	Days to fruit maturity	Number of fruits
ontrol	109.38±2.55 a	6.84±0.05 a	28.28±1.46 a	4.55±0.04 d
60 kg ha^{-1}	106.44±2.94 b	4.78±0.03 bc	24.17±1.22 b	6.06±0.01 c
70 kg ha^{-1}	105.33±1.97 b	4.06±0.07 c	23.93±0.97 b	6.71±0.01 b
80 kg ha^{-1}	104.67±3.05 bc	2.98±0.08 d	20.05±0.88 c	7.50±0.03 a
90 kg ha^{-1}	102.66±1.89 c	5.51±0.04 b	22.55±1.37 bc	7.23±0.05 a

LSD value for days to flowering at 5% level of probability = 2.11

LSD value for days to fruit set at 5% level of probability = 0.96

LSD value for days to fruit maturity at 5% level of probability = 2.57

LSD value for Number of fruits at 5% level of probability =0.42

3.2 Days to Fruit Set

Results (Table 2) show that the highest days for fruit set (6.84) were observed in plants which were untreated, while the lowest days to fruit set (2.98) were observed in plants treated with 80 kg phosphorus ha^{-1}. It might be due to the fact that after pollination energy requires for fruit set is provided by ATP. Phosphorus has an important role in plant process that involves energy transfer. High-energy phosphate, are constituents of the chemical structures of ATP and adenosine diphosphate (ADP), that drives many chemical reactions within the plant (Malik, 1994). These results were in relation to (Khan et al., 2000) who reported that with lowest dose of nitrogen combined with phosphorus and potassium enhances flowering, fruit setting and developing of reproductive parts. According to (Mohammad et al., 2011) Phosphorus and Zinc both improve flower formation, while (Wajid et al., 2010) reported that high concentration of N depressed reproductive growth.

3.3 Days to Fruit Maturity

Results show that the highest number of days to fruit maturity (Table 2) of strawberry plants (28.28) was observed in control plants, while the lowest number of days to fruit maturity (20.05) was observed in the plants treated with phosphorus at 80 kg ha-^{1}. The lower number of days to fruit maturity might be due to the fact that energy is required after fruit set to transport photosynthate to fruits which is provided by ATP. Phosphorus has an important role in plant process that involves energy transfer. High-energy phosphate, are constituents of the chemical structures of ATP and adenosine di phosphate (ADP), that drives many chemical reactions within the plant. Phosphorus at adequate level increases the rate of transformation and enhances early maturity (Malik, 1994; Khan et al., 2000; better crops, 1999). These results were in correspondence with (Asgedom & Becker, 2011; Arif et al., 2005) who

stated that phosphorus enhances early fruit maturity, crop development and seed production. It synchronizes the germination process and enhances final yield.

3.4 Number of Fruits Plant^{-1}

According to Table 2, the highest numbers of fruits (7.50) were observed in the plants that were treated with 80 kg Phosphorus ha^{-1}, while the lowest numbers of fruits (4.55) were observed in control plot. Phosphorus (P) is major elements for growth and metabolism of plant and plays a crucial role in different plant processes such as synthesis of nucleic acids and membranes, energy metabolism, respiration, enzyme regulation, nitrogen fixation and photosynthesis. Optimum phosphorus nutrition affects many aspects of plant development. It enhances flowering, fruiting and root growth (Raghothama, 1999) These results were in correspondence to (Khan et al., 2000) who stated that the highest number of fruits plant^{-1} might be due to vigour of plant and more number of leaves resulting by improved root growth due to phosphorus fertilizer. While less number of fruits may be due to the poor nutritional status of plant. According to (Mohammad et al., 2011) Phosphorus and Zinc both improve flower formation so there will be more fruit set and more number of fruits plant^{-1}.

3.5 Fruit Size (cm^3)

According to Table 3, the highest fruit size (6.42 cm^3) were noted in plants treated with 70 kg phosphorus ha^{-1}, while the smallest fruit sizes (4.27 cm^3) were observed in control plants. ATP is an energy phosphate required for synthesis of starch. These energy rich ATPs can also be transmitted to other coenzymes like uridine triphosphate (UTP) and guanosine (GTP), which are required for cellulose and sucrose synthesis (Marschner, 1995). These results were in correspondence with (Abd-Alla et al., 1996; Sainju & Singh, 2003) concluded that phosphorous enhances healthy root growth which helps in efficient utilization of water and nutrients resulting a strong stem and foliage growth, production of large number of flowers and early fruit setting. As a result, phosphorus enhances the number and production of tomato fruits.

Table 3. Effect of Phosphorus Levels on Fruit Size Cm3, Total Yield Tons Ha^{-1}, Ascorbic Acid and Percent Acidity on Strawberry

Phosphorus	Fruit size cm^3	Total yield tons' ha^{-1}	Ascorbic acid (mgml^{-1})	Percent acidity (%)
Control	4.27±0.06 b	2.18±0.01 c	53.71±1.35 b	0.57±0.00 c
60 kg ha^{-1}	5.81±0.05 a	2.60±0.01 bc	62.61±1.44 a	0.64±0.01 a
70 kg ha^{-1}	6.42±0.09 a	2.94±0.02 b	61.56±1.28 a	0.62±0.01 ab
80 kg ha^{-1}	5.74±0.07 a	3.61±0.01 a	59.07±1.57 a	0.60±0.02 bc
90 kg ha^{-1}	5.86±0.05 a	3.19±0.03 ab	59.20±1.39 a	0.62±0.01 ab

LSD value for Fruit size at 5% level of probability = 1.25

LSD value for Total yield at 5% level of probability =0.62

LSD value for Ascorbic acid at 5% level of probability = 4.21

LSD value for Percent acidity at 5% level of probability =0.033

3.6 Total Fruit-Yield Ha^{-1}

The highest total fruit yield (3.61 tons ha^{-1}) were observed in the plants treated with phosphorus at 80 kg ha^{-1} (Table 3), while the lowest yield (2.18 tons ha^{-1}) were noted with in control plants. The highest total yield might be due to increased number of fruits and size plant^{-1} (Khan et al., 2000). These findings were in relation with the findings of (Naik & Srinivas, 1992). They reported that seed yield depends upon the number of pods, seeds and average seed weight pod^{-1} (Ali & Iqbal, 2003; Wajid et al., 2010) reported that nitrogen increases vegetative growth so automatically reproductive stag is delayed while phosphorus enhances reproductive growth and the yield is high. According to (Abd-Alla et al., 1996; Sainju & Singh, 2003) phosphorous has a major role in enhancing early flowering, fruit set and maturity. It also increases number of fruits and production of fruits.

3.7 Ascorbic Acid (mg ml^{-1})

According to Table 3, the highest concentration of ascorbic acid (62.61) was observed in the fruit of plants treated with phosphorus at 60 kg ha^{-1}, while the lowest concentration of ascorbic acid (53.71) was recorded in control plants. There was no significant difference among phosphorus treatments. Phosphorus is organic acid and increases acidity in fruit juice. These results were in relation to (Abd-Alla et al., 1996; Sainju & Singh, 2003; Winsor, 1973) who stated that lower phosphorus concentrations will produce fruits with high acidity These results were in correspondence with (Su, 1974) who stated that Phosphorus increases taste, hardiness and vitamin C content, while it also improves colour of skin and pulp of tomato fruit.

3.8 Percent Acidity

Results (Table 3) show that the highest percent Acidity value (0.64) were observed in the fruits of plants treated phosphorus at 60 kg ha^{-1}, while the lowest percent Acidity (0.57) recorded in control fruits of plants. The fruit quality was significantly influenced by sugar and acid ratio. A decrease in sugar content and acidity ratio resulted in better tasting in tomato fruit (Wuzhong, 2002). These results were in collaboration with (Fandi et al., 2010) who stated that phosphorus at low concentration gives the highest total soluble solids, percent acidity and lowest pH.

3.9 Total Soluble Solids (Brix^{0})

According to Table 4, the highest total soluble solids (7.83) for strawberry fruit was noted in the fruits of plants treated with phosphorus at 60 kg ha^{-1}, while the lowest total soluble solids (6.30) were recorded in fruits of control plants. Phosphorus at low concentration increases total soluble solids according to (Balibrea et al., 2006) who stated that an increase in Total soluble solids of tomato fruits may depend on a higher sugar import and accumulation. These results were in collaboration with (Winsor, 1973) who described that at high nitrogen or at low phosphorus concentrations plants will result in fruits having high soluble solids content.

Table 4. Phosphorus Levels Effect on Total Soluble Solids, pH and Number of Runners on Strawberry

Phosphrous	Total Soluble Solids ($Brix^0$)	pH	Number of Runners
Control	6.30±0.15 c	2.33±0.02 a	11.500
60 kg ha^{-1}	7.83±0.13 a	2.07±0.01 c	13.500
70 kg ha^{-1}	6.97±0.17 b	2.17±0.01 bc	12.833
80 kg ha^{-1}	6.37±0.11 bc	2.23±0.02 ab	12.000
90 kg ha^{-1}	6.47±0.10 bc	2.20±0.01 abc	12.890

LSD value for Total Soluble Solids at 5% level of probability = 0.633

LSD value for pH at 5% level of probability = 0.14

LSD value for Number of runners at 5% level of probability = 3.34

3.10 pH

All of the phosphorus treatments decreased fruit pH (Table 4). The lowest pH value (2.07) was observed in the fruits of plants treated with phosphorus at 60 kg ha^{-1}, while the highest pH value (2.33) 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. These results were in correspondence with (Abd-Alla et al., 1996; Sainju et al., 2003; Kaminwar & Rajagopal, 1994) who said that at low phosphorus concentrations plant will produce fruits having high acidity.

3.11 Number of Runners

The number of runners of strawberry plant (Table 4) had a non-significantly effect by different levels of phosphorus. However, the mean values of data show that the highest number of runner's value (13.00) was observed in the plants treated with 60 kg Phosphorus ha-1, while the lowest number of runners (11.500) was noted in untreated plants.

In the performed experiment cultivar Chandler showed non-significant effect of phosphorus on number of runners of strawberry plant, it might be due to the same genetic diversity of the plant.

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