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EFFECT OF PHOSPHORUS, POTASSIUM AND SULPHUR-ENRICHED FOLIAR FERTILIZER ON APPLE CULTIVARS SUPER CHIEF AND JEROMINE IN KINNAUR'S DRY TEMPERATE REGION

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ABSTRACT

In the dry temperate region of Kinnaur, Himachal Pradesh, apple (*Malus domestica* Borkh.) cultivation is hindered by nutrient deficiencies and intermittent drought, necessitating efficient nutrient management strategies. Foliar fertilization, which involves the direct application of nutrients to leaves, has emerged as a promising technique to overcome these challenges. This study aimed to evaluate the impact of Aquafert Foliar, containing 5% phosphorus, 26% potassium, and 13% sulphur, on the growth, yield, and quality of apple cultivars Super Chief and Jeromine. The experiment was conducted at the Vegetable Research Station, Kalpa, Kinnaur, with applications of Aquafert Foliar at 100g/plant at 15, 30, and 45 days after petal fall. The results indicated significant improvements in growth parameters, such as shoot extension (32.40 cm), trunk diameter (58.68 mm), and plant height (337.75 cm), particularly in the Super Chief cultivar. Additionally, Aquafert Foliar at 75g/plant enhanced yield attributes, including fruit count (151 fruits/tree) and productivity (101.31 mt/ha), with Jeromine outperforming Super Chief in these aspects. The highest fruit weight (224.9 g) and TSS (12.25 Brix) were recorded with Aquafert Foliar at 75g/plant. The study concluded that while Super Chief showed superior vegetative growth, Jeromine excelled in fruiting, with significant interaction effects observed between treatments and cultivars across growth, flowering, fruiting, and quality parameters. This highlights the potential of foliar fertilization in optimizing apple production under the challenging conditions of the region.
Keywords: Aquafert foliar fertilizer, super chief, jeromine, productivity, kinnaur.

Introduction

Kinnaur, Himachal Pradesh, plays a key role in apple cultivation, boosting the local economy and global nutrition. By 2022-23, the apple-growing area increased from 670 to 10,925.5 hectares, with the Royal Delicious variety making up 90% of production (Anonymous, 2023). During this period, Kinnaur produced 83,324 metric tons of apples with an average yield of 7.63 mt/ha, exceeding the statewide average of 5.82 mt/ha (Anonymous, 2023). Although cultivation has expanded to lower elevations, the unique climate of higher regions yields smaller but higher-quality apples. In 2023, severe weather led to a 40% production decline (Anonymous, 2023), raising concerns about the sustainability of apple quality and productivity. Consequently, the horticulture sector is exploring new cultivation methods, particularly fertilization techniques like soil application and foliar feeding. Foliar feeding, such as applying fertilizers like Aquafert directly to leaves, is crucial in regions like Kinnaur, where nutrient deficiencies, drought, and dry temperate climates are common. This method overcomes soil limitations, providing essential nutrients during key growth stages, which boosts resilience and productivity (Amiri *et al.,* 2008). Soil-applied fertilizers enhance crop yields, but overuse may result in nutrient leaching, groundwater pollution, and diminished nutrient uptake. Phosphorus,

potassium, and sulphur are essential for apple quality and yield, supporting cellular processes, photosynthesis, and sugar metabolism (Srivastava, 2012). Soil degradation and poor farming methods have lowered apple yields and profits. Foliar fertilization offers a sustainable alternative by reducing fertilizer use and environmental impact, regardless of soil pH or root health, especially in poor soils. For high-quality yields in Kinnaur's challenging conditions, a balanced approach of combining foliar and soil fertilization is recommended (Amiri *et al.* 2008). Potassium, essential for plant metabolism, improves fruit yield and quality, with foliar potassium applications enhancing yield, reducing fruit drop, and increasing fruit size, weight, firmness, and total soluble solids in apples and other fruits (Dbara *et al.* 2018). Foliar applications of KNO_3 effectively increase yield, fruit weight, size, and total soluble solids (TSS) content while decreasing titratable acidity (TA) (Jawandha *et al.* 2017). Despite extensive research, the impact of foliar fertilization on apple trees in dry temperate regions like Kinnaur is underexplored. This study evaluates Aquafert foliar fertilizer's effects on the growth, yield, and fruit quality of Super Chief and Jeromine apple cultivars, offering insights into effective nutrient management in these environments.

Materials and Methods

The experiment was conducted in 2022 at the Vegetable Research Station, Kalpa Farm's High-Density Apple demonstration orchard in Kinnaur, Himachal Pradesh, focusing on 7-year-old Super Chief and Jeromine apple trees grafted on MM 106 and M9 clonal rootstocks, respectively. The trees, spaced at 2.5 x 1 meters apart, were grown in sandy loam soil with an acidic to neutral pH with good fertility. The orchard is situated at an elevation of 2,740 meters above sea level, with coordinates ranging from 76° 46' 29" to 78° 41' 34" E longitude and 31° 44' 57" to 32° 59' 57" N latitude. The study employed a randomized block design (RBD) with five treatments, each replicated three times, with three trees per replicate. The treatments included applications of Aquafert Foliar Apple, a 100% soluble inorganic crystalline powder fertilizer containing 5% Phosphorus (P), 26% Potassium (K), and 13% Sulphur (S), enriched with essential nutrients and low in chlorine and harmful heavy metals. The treatments were as follows: T_1: 100 g per plant applied 15, 30, and 45 days after petal fall; T_2: 100 g per plant applied 15 and 45 days after petal fall; T_3: 75 g per plant applied 15, 30, and 45 days after petal fall; T_4: 75 g per plant applied 15 and 45 days after petal fall; and T_5: Control, with no foliar application of inorganic fertilizer during the early fruit development stage. The study recorded various tree physical parameters and yield metrics as follows: Ten shoots were randomly selected around the tree periphery, and their extension growth before pruning was measured (cm shoot^{-1}). Fruit set was recorded three weeks after petal fall, with the percentage calculated using Westwood's formula. Fruit yield was measured during harvest season, expressed in kg/tree using a 24 kg standard apple box. The average fruit weight was determined with an electronic balance (g/fruit) from a sample of ten fruits. Fruit diameter was measured using a Vernier caliper, and fruit firmness was assessed with a Magness and Taylor pressure tester (kg/cm²). Total soluble solids (TSS) content was measured using a Zeiss hand refractometer at 20°C. Shelf life was determined by storing ten randomly selected fruits under normal conditions, with five fruits kept at room temperature. Data were analyzed using ANOVA, and the critical difference (CD) was calculated to determine significant variation at the 5% probability level (Steel and Torrie, 1980).

Results and Discussion

Growth attributes

Table 1 shows the effects of Aquafert fertilizer on the growth of apple cultivars Super Chief and Jeromine. The highest shoot growth (32.40 cm), trunk diameter (58.68 mm), plant height (337.75 cm), and N-S spread (178.75 cm) were seen in treatment T_1 (100 g/plant, applied 15, 30, and 45 days after petal fall). The maximum E-W spread (158.75 cm) occurred in T_3. The lowest shoot growth (26.62 cm) was in T_3, while T_2 (100 g/plant, applied 15 and 45 days after petal fall) showed the minimum trunk diameter (50.00 mm) and height (297.50 cm). The smallest E-W (103.75 cm) and N-S (93.75 cm) spreads were in T_4. The Super Chief cultivar showed significantly higher shoot extension (35.58 cm), plant height (334.40 cm), and plant spread E-W (142.00 cm) and N-S (142.70 cm) than Jeromine, with no significant difference in trunk diameter. Significant interactions between treatments and cultivars were found for all growth attributes except trunk diameter and plant height. Super Chief exhibited the highest shoot extension (39.86 cm) and N-S spread (200 cm) under T_1, while Jeromine had the largest E-W spread (195 cm) under T_3 but the lowest shoot extension (22.37 cm) under T_2. Jeromine recorded E-W and N-S spreads of 87.50 cm and 62.50 cm, respectively, under T_4. Aquafert (100 g/plant) applied 15, 30, and 45 days after petal fall significantly enhanced growth, with Super Chief on MM 106 rootstock outperforming Jeromine on M9. These

findings align with Dodangeh *et al*. (2012), showing a favorable interaction effect for Super Chief with Aquafert. The increase in trunk girth is linked to phosphorus's role in cell and organelle composition (Kumar and Chandel, 2004). Potassium in Aquafert correlated with tree height due to its role in plant metabolism and enzyme systems (Afzal *et al.* 2015).

Flowering attributes

Significant differences in flowering attributes were observed between the Super Chief and Jeromine apple cultivars when treated with varying concentrations of Aquafert fertilizer. Treatment T_1, which involved applying 100 g per plant on days 15, 30, and 45 after petal fall, led to the highest total flower count (536.25 flowers/tree) and fruit set (223.00 fruits/tree), but the lowest percent fruit set (41.79%). In contrast, Treatment T_2, applied only on days 15 and 45, resulted in a higher percent fruit set (67.73%) but lower flower count (196.25 flowers/tree) and fruit set (109.25 fruits/tree). Jeromine cultivar recorded the highest values across total flowers (392.50 flowers/tree), fruit set (220.20 fruits/tree), and percent fruit set (60.32%), with a significant interaction between treatments and cultivars noted. The Jeromine cultivar performed best under Treatment T_3, with the highest flower count (547.50 flowers/tree) and fruit set (305.00 fruits/tree). Although the flower count under T_1 was similar for both Super Chief and Jeromine, Jeromine under T_3 had a higher fruit set. The lowest fruit set (142.50 fruits/tree) was in Jeromine under T_2, despite T_2 having the highest fruit set percentage (75.46%). Super Chief under T_1 had the lowest fruit set percentage, similar to Jeromine under T_1 and T_4. Aquafert application at 100 g per plant, particularly at 15, 30, and 45 days after-petal fall, significantly improved flowering, with Jeromine showing the greatest enhancement. The variation in response is attributed to rootstock characteristics: MM 106, a vigorous rootstock, produced fewer flowers and lower fruit set, whereas M9, a dwarfing rootstock, promoted more flowers and limited vegetative growth, enhancing flowering in Jeromine. These results align with those of Dodangeh *et al.* (2012). A significant interaction between treatments and cultivars was also observed.

Fruiting attributes: Table 3 illustrates the significant influence of varying concentrations of Aquafert fertilizer on fruiting characteristics in two apple cultivars, Super Chief and Jeromine. Notably, Treatment T_3, involving the application of Aquafert at 75 g per plant, applied 15, 30, and 45 days after petal fall, yielded significantly higher fruit counts (151 fruits/tree), increased yield (25.33 kg/tree), and enhanced productivity (101.31 mt/ha). Conversely, Treatment T_2, applying Aquafert at 100 g per plant, applied 15 and 45 days after petal fall, exhibited notably lower values for the same parameters. Aquafert foliar application enhances fruit weight by improving phosphorus and potassium availability, boosting CO_2 assimilation and carbohydrate synthesis in plants (Baseerat *et al.* 2018). Increased fruit yield is associated with better phosphorus, potassium, and sulfur use (Amiri *et al.* 2008). Sulphur deficiency negatively influences biomass, morphology, yield, and nutrition, while sufficient sulfur improves amino acid synthesis and photosynthesis, leading to higher yields (Narayan *et al*. 2022).

This study shows that foliar fertilizers like Aquafert enhance fruit yield by providing essential nutrients. Treatment T_4 recorded the highest fruit weight, while T_3 had the lowest (181.3 g/fruit), similar to the control (T_5). Azeem *et al.* (2018) also emphasized the role of foliar macronutrients in plant functions. The cultivar Jeromine exhibited a notably higher fruit count (136.8 fruits/tree), yield (21.21 kg/tree), and productivity (84.86 mt/ha). Super Chief cultivar showed a greater fruit weight (222.58 g/fruit) during the study. Significant interactions between Aquafert foliar fertilizer treatments and cultivars influenced fruiting attributes in both varieties. In Jeromine, Treatment T_3 resulted in the highest fruit count per tree (225.50), yield (32.49 kg/tree), and productivity (129.95 mt/ha). Conversely, Super Chief under Treatment T_2 showed the lowest fruit count per tree (56.00). The lowest yield (11.85 kg/tree) and productivity (47.39 mt/ha) were observed in the control (T_5) for Super Chief, which received no foliar application during early fruit development. However, the highest fruit weight (236.00 g/fruit) was recorded in Super Chief under Treatment T_1, while the lowest fruit weight (142.40 g/fruit) was observed in Jeromine under Treatment T3. Phosphorus is crucial for fruit size, firmness, and yield (Baseerat *et al.* 2018). Applying Aquafert at 100 g per plant improved fruiting attributes across all treatments, with each showing better results than the control.

Quality attributes

The data in Table 4 indicates that various treatments of Aquafert Foliar Apple significantly influenced fruit size (length & breadth), firmness, and total soluble solids (TSS) in both apple cultivars. Treatment T_4 (Aquafert @ 75 g/plant at 15 and 45 days after petal fall) produced the largest fruit size (75.21 mm length, 78.74 mm breadth) and highest TSS (121.25°Brix). Except for T_3, which had reduced fruit

length, fruit size remained high across treatments. Differences in breadth and TSS were not significant, but fruit firmness varied, with T_3 showing the highest (7.93 kg/cm²) and T_2 the lowest (6.01 kg/cm²). Super Chief had longer fruits, while Jeromine had firmer fruits. Phosphorus and potassium were key in improving fruit quality (Srivastava, 2012). Aquafert had no significant effect on fruit size or TSS between cultivars, but interactions between Aquafert treatments and cultivars affected other fruit attributes, excluding fruit breadth and TSS. Super Chief produced the longest fruits (77.91 mm) under T_1, while Jeromine had the shortest (65.60 mm) under T_3 but showed higher firmness (8.56 kg/cm²). Potassium enhances TSS by regulating stomatal function, enzyme activity, cell growth, and sugar production (Ashraf *et al.* 2010). Increased potassium uptake improves CO_2 assimilation and carbohydrate synthesis, thus raising TSS levels. This aligns with Daroshenko *et al.* (2005), who found that optimal potassium levels increase TSS in apples. Aquafert applied at 100 g per plant (15, 30, and 45 days after petal fall) significantly improved fruit quality. The Super Chief cultivar showed larger fruit size, while Jeromine had higher TSS and firmness, with treatment and cultivar interactions playing a key role in quality improvement.

Figure 1 shows the impact of different aquafert fertilizer concentrations (T_1 to T_5) on the harvesting date and shelf life of two apple cultivars, Super Chief and Jeromine. The harvesting date remained consistent across treatments, with most apples harvested on 07/10/2022, except for Super Chief in T_4, which was harvested earlier on 10/07/2022. Shelf life varied more significantly. Super Chief had the longest shelf life under T_1, T_3, T_4, and T_5 (until 23/01/2023), but under T_2, it expired earlier (03/12/2022). For Jeromine, T_1 and T_3 extended shelf life to 23/01/2023, while T_2, T_4, and T_5 shortened it to 06/01/2023. Thus, fertilizer treatments notably influenced shelf life but had minimal impact on harvesting dates.

Further, figure 2 illustrates the effect of Aquafert concentrations on the shelf life of Super Chief and Jeromine apple cultivars. For Super Chief, T_1, T_4, and T_5 extended shelf life to 108 days, while T_2 and T_3 resulted in shorter lives of 57 and 71 days. Jeromine had the longest shelf life (108 days) under T_1 and T_3, with T_2, T_4, and T_5 averaging 91.5 days. Jeromine's overall mean shelf life was higher (98.1 days) than Super Chief's (90.4 days), highlighting each cultivar's unique response to Aquafert concentration.

Conclusion

Aquafert Foliar Apple revealed significant efficacy in enhancing apple tree growth and productivity. The study showed 100 g/plant (applied at 15, 30, and 45 days after-petal fall) improved growth and flowering/fruiting for the Super Chief cultivar. Conversely, 75 g/plant enhanced fruiting (count, yield, productivity) for Jeromine. These findings highlight the importance of targeted foliar fertilization, especially in nutrient-poor, drought-prone areas. The treatment-cultivar interaction suggests tailored fertilization is crucial for efficient apple production in challenging conditions.

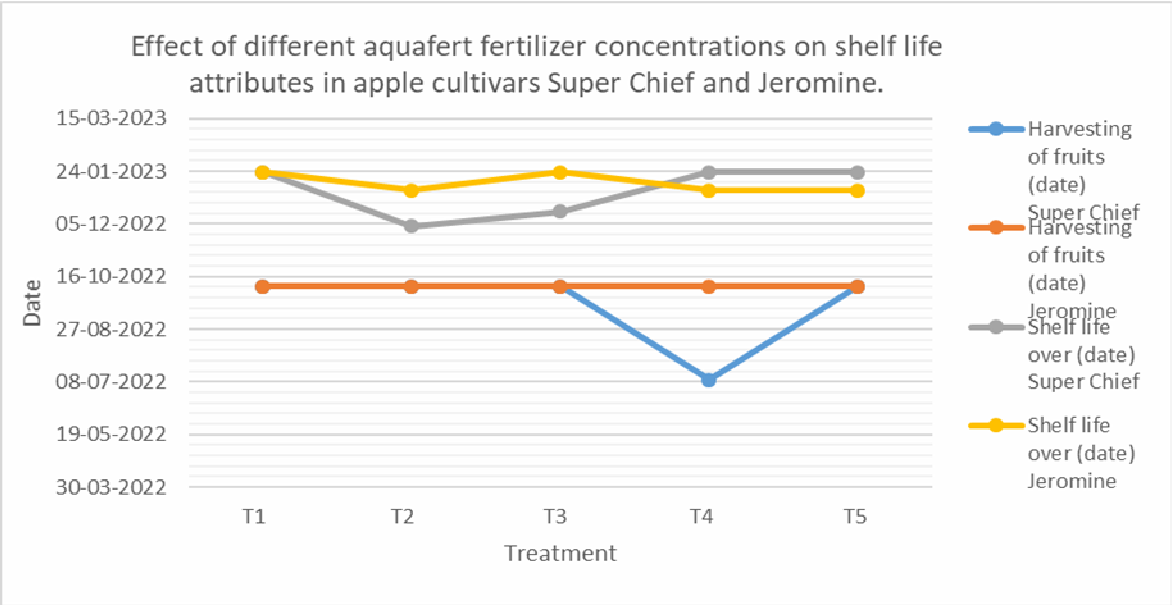

Fig. 1: Effect of aquafert fertilizer concentrations on harvesting date and shelf life over (date) in apple

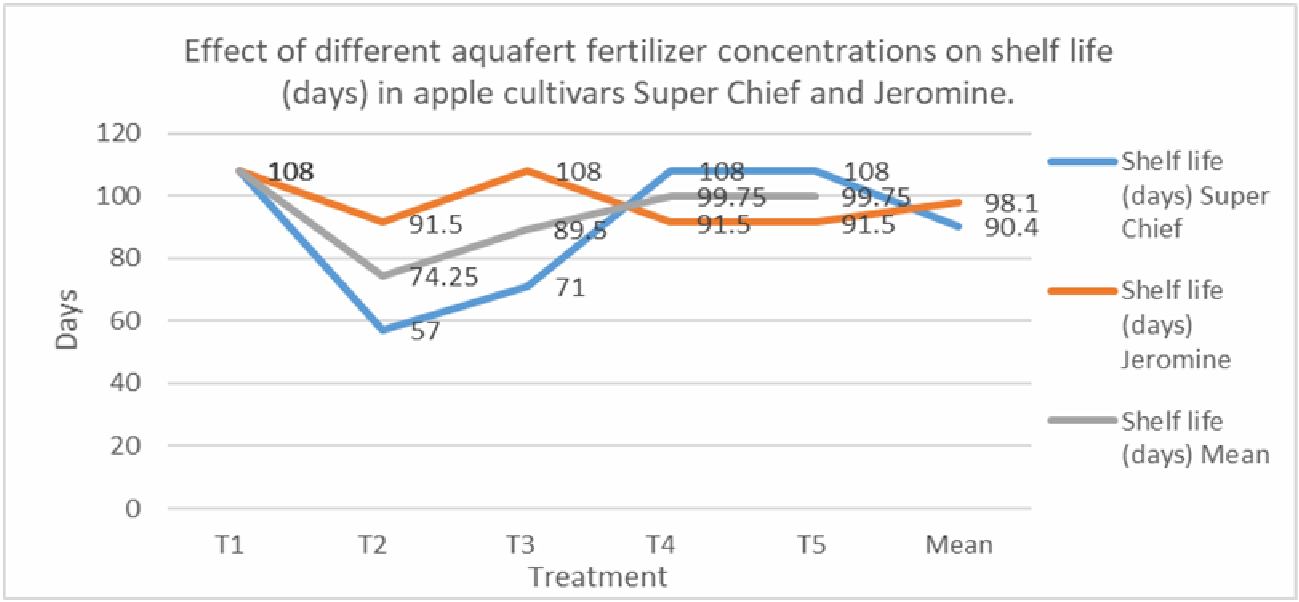

Fig. 2: Effect of aquafert fertilizer concentrations on shelf life attributes (days) in apple cultivars.

Table 1: Effect of aquafert fertilizer concentrations on growth attributes in apple cultivars.

Treatment	Shoot extension growth (cm)			Trunk Diameter (mm)			Plant Height (cm)			Plant Spread E-W (cm)			Plant Spread N-S (cm)		
	Super Chief	Jeromine	Mean	Super Chief	Jeromine	Mean	Super Chief	Jeromine	Mean	Super Chief	Jeromine	Mean	Super Chief	Jeromine	Mean
T1	39.86	25.08	**32.40**	58.90	58.45	**58.68**	359.00	316.50	**337.75**	170.00	117.50	**143.75**	157.50	200.00	**178.75**
T_2	33.41	22.37	**27.89**	58.37	41.63	**50.00**	325.00	270.00	**297.50**	152.50	87.50	**120.00**	139.50	102.50	**121**
T_3	29.78	23.46	**26.62**	57.76	46.01	**51.89**	333.00	306.00	**319.50**	122.50	195.00	**158.75**	146.50	147.50	**147**
T_4	39.42	24.95	**32.18**	56.44	51.96	**54.20**	337.50	277.50	**307.50**	120.00	87.50	**103.75**	125.00	62.50	**93.75**
T_5	35.44	23.84	**29.94**	53.65	49.44	**51.55**	317.50	308.00	**312.75**	145.00	135.00	**140.00**	145.00	157.50	**151.25**
Mean	**35.58**	**23.94**		**57.02**	**49.50**		**334.40**	**295.60**		**142.00**	**124.50**		**142.7**	**134**	
$CD_{0.05}$															
A			0.308			NS			11.79			7.302			NS
B			0.487			NS			18.64			11.546			21.85
AxB			0.689			NS			NS			16.329			30.90

Table 2: Effect of aquafert fertilizer concentrations on flowering attributes in apple.

Treatment	Total Number of Flowers (Flowers/tree)			No of Fruits Set (fruit set/tree)			Fruit set (%)		
	Super Chief	Jeromine	Mean	Super Chief	Jeromine	Mean	Super Chief	Jeromine	Mean
T1	537.50	535.00	**536.25**	198.00	248.00	**223.00**	37.20	46.38	**41.79**
T_2	250.00	142.50	**196.25**	110.50	108.00	**109.25**	59.99	75.46	**67.73**
T_3	262.50	547.50	**405.00**	130.00	305.00	**217.50**	48.42	55.72	**52.07**
T_4	380.00	292.50	**336.25**	176.50	180.00	**178.25**	46.04	67.26	**56.65**
T_5	200.00	445.00	**322.50**	109.50	260.00	**184.75**	57.29	56.80	**57.05**
Mean	**326.00**	**392.50**		**144.90**	**220.20**		**49.79**	**60.32**	
$CD_{0.05}$									
A			7.26			7.87			2.897
B			11.48			12.44			4.58
AxB			16.24			17.59			6.478

Table 3: Effect of aquafert fertilizer concentrations on fruiting attributes in apple

Treatment	Total fruits per tree			Fruit Weight (g/fruit)			Yield (kg/tree)			Productivity (mt/ha)		
	Super Chief	Jeromine	Mean	Super Chief	Jeromine	Mean	Super Chief	Jeromine	Mean	Super Chief	Jeromine	Mean
T1	119.50	142.50	**131**	236.20	167.90	**202.05**	20.23	21.08	**20.65**	84.90	84.33	**84.62**
T_2	56.00	72.00	**64**	212.40	189.10	**200.75**	14.22	15.42	**14.82**	56.86	61.70	**59.28**
T_3	76.50	225.50	**151**	220.20	142.40	**181.3**	18.17	32.49	**25.33**	72.66	129.95	**101.31**
T_4	93.00	89.00	**91**	232.00	217.80	**224.9**	20.21	12.84	**16.52**	80.86	51.37	**66.12**
T_5	60.50	155.00	**107.75**	212.10	166.10	**189.1**	11.85	24.23	**18.04**	47.39	96.94	**72.17**
Mean	**81.1**	**136.8**		**222.58**	**176.66**		**17.136**	**21.212**		**68.53**	**84.86**	
$CD_{0.05}$												
A			6.633			8.403			1.366			7.785
B			10.488			13.286			2.159			12.309
AxB			14.832			18.789			3.054			17.407

Table 4: Effect of aquafert fertilizer concentrations on quality attributes in apple

Treatment	Length of fruit(mm)			Breadth of fruit (mm)			Pressure (kg/cm^2)			TSS (°Brix)		
	Super Chief	Jeromine	Mean	Super Chief	Jeromine	Mean	Super Chief	Jeromine	Mean	Super Chief	Jeromine	Mean
T1	77.91	67.49	**72.70**	82.34	73.11	**77.73**	6.17	6.22	**6.20**	9.75	12.00	**10.88**
T_2	73.25	72.95	**73.10**	78.93	76.24	**77.59**	6.59	5.42	**6.01**	12.75	11.00	**11.88**
T_3	73.39	65.60	**69.50**	79.98	69.14	**74.56**	7.39	8.46	**7.93**	10.50	11.50	**11.00**
T_4	75.67	74.75	**75.21**	81.08	76.40	**78.74**	6.66	6.70	**6.68**	11.75	12.75	**12.25**
T_5	73.40	69.31	**71.36**	80.08	72.82	**76.45**	5.19	7.97	**6.58**	10.50	10.25	**10.38**
Mean	**74.72**	**70.02**		**80.48**	**73.54**		**6.40**	**6.95**		**11.05**	**11.50**	
CD												
			2.258			2.962			0.474			NS
			3.57			NS			0.749			NS
			5.048			NS			1.059			NS

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