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OPTIMIZING PLANTING DEPTH AND FERTILIZER APPLICATION FOR EMERGENCE PERCENTAGE, VIGOR SCORE, AND YIELD OF POTATO PLANTS

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Abstract

A field experiment was conducted over two consecutive seasons, 2019-20 (first phase) and 2020-21 (second phase) in Kasur and Lahore region. The objective of the study was to investigate the impact of different planting depth (8cm, 10cm and 12cm) and three foliar sprays containing $ZnSO_4$ (179.7 g, 119.8 g and 59.9g) $FeSO_4$ (5.3 g, 10.6g and 15.9 g) on six potato varieties (Chipsona, Kuroda, Asterix, Sante, Sarpomira and Mosika). The research was carried out in split-split block design with three replications. The main plots were designated for foliar application, the sub plots were designated for maintaining depth level, and sub-sub plot were designated for arranging potato varieties to investigate their interaction on emergence rate, seedling vigor and yield per plant. The results obtained from the study demonstrate a significant impact of 10cm depth on emergence percentage and plant vigor score. Foliar application of $ZnSO_4$+$FeSO_4$ (59.9g+15.9g) at 10cm planting depth can be optimized for good tuber yield for all investigated varieties. Among all varieties Chipsona exhibited superior results following by Mosika, Kuroda, Sante and Sarpomira, while Asterix exhibited least results.

Keywords: Potato, Tuber, Emergence, Vigor, Yield, Foliar Application, $ZnSO_4$, $FeSO_4$, Planting Depth, 10cm.

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INTRODUCTION

Potato (*Solanum tuberosum* L.) is an important starch producing crop of Solanaceae family (Al-Shareefi, Abbass, & Abdulhussein, 2020). It is a perennial herbaceous plant (Jurayev, Jurayev, Atamurodov, Sobirov, & Najmiddinov, 2022). The nutritional and industrial usage of potato makes its worldwide worth unneglectable (Kot *et al*., 2020). FAO claims that its global production exceeded to 400 MT (Devaux *et al*., 2021).

More consumption of potato is may be due to its nourishing, less cholesterol and fat free nature (Visvanathan, Jayathilake, Chaminda Jayawardana, Liyanage, & Agriculture, 2016).

The significance of potato can be judge by the assumption that it can be among leading crops to beat future hunger of the world (Memon, 2017). The plant is cultivated every year in Pakistan (Hassan, Jajja, Asif, & Foster, 2021) in three distinct seasons: spring, summer, and autumn (Ali, Nawaz, Irshad, Khan, & Design, 2015).

Farmers occasionally harvest the crop before it is fully mature since harvesting at an early stage, particularly in the fall, generally fetches good prices on the market. Even if early harvesting results in a lower yield, the market price is greater. This is partially true for crops in the fall when there are few cooking tubers available. About 40% of the autumn crop is preserved for marketing in the summer, while the majority is sold fresh.

In 2020, Pakistan exported fresh and chilled potato worth $ 69 million while imported potatoes valued $ 19.2 million from France, Egypt, Bhutan, USA, UK, China, Afghanistan, Germany, Iran and Netherland (TrendEconomy, 2020). The demand and supply ratio of potato changes throughout the year but it’s essentialness remains same.

The planting depth and nutrient application (especially Zinc and Iron) are two important parameters that determine the growth, yield, and quality of the crop for successful of potato production. The depth of sowing is bestowing factor affecting the tuber yield.

Proper depth is crucial for stolon formation as it determines aerial stems growth (Thornton, 2020). According to Ilyas and Ayub (2017), tuber plantation beyond the depth of 15cm has pessimist effect on tuber quality and yield. The proposed study suggested the use of three depth level 8cm, 10cm and 12cm to determine its effect on starch content of six potato varieties at various levels of $ZnSO_4$ and $FeSO_4$.

The foliar application of micronutrient like iron is essential for proper flowering and tuber bulking in potato due to its immobile nature. Zinc is also crucial for quality tuber production (Dev *et al*., 2020). It helps in translocation of material in photosynthesis that leads to increase in tuber size. Present study was designed to evaluate the impact of planting depth in conjunction with $ZnSO_4$ and $FeSO_4$ on emergence percentage, vigor score and yield of potato tubers in Kasur and Lahore region.

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MATERIAL AND METHODS

Location and Climate

The first phase was practiced at Hassan and Co farm under the endowment of Perfect Agro Food Industries Kalio, Kasur during the autumn growing season of the year 2019-20. The site is located at 31.036 latitude and 74.36 longitude with Chenab river as irrigation source. The second phase of the research was carried out at Faculty of Agricultural Sciences, University of the Punjab, Lahore with BRB canal irrigation source.

Treatment and Design:

The proposed study suggested to use three combinations of $ZnSO_4$ and $FeSO_4$ ($ZnSO_4$ 179.7 $FeSO_4$ 5.3, $ZnSO_4$ 119.8 $FeSO_4$ 10.6, and $ZnSO_4$ 59.9 $FeSO_4$ 15.9) on three depth levels of six potato verities V_1 (Sarpomira), V_2 (Asterix), V_3 (Kuroda), V_4 (Chipsona), V_5 (Sante) and V_6 (Sante). All management practices for each variety was kept constant except for studied parameters like planting depth and $ZnSO_4$+$FeSO_4$ combinations. The study was conducted using a split-split block design, with three replications. The primary plots were assigned for the purpose of foliar treatment, while the secondary plots were designated to control the depth level. Furthermore, the tertiary subplots were specifically allocated to arrange different potato varieties in order to examine their impact on emergence rate, seedling vigour, and yield per plant. The foliar application of nutrient was done at flowering stage indicated the effect of foliar spray on yield parameter.

RESULTS AND DISCUSSION

Emergence Percentage

Emergence rate was observed to have an inverse relationship with depth as shown in Table 1. In both phases of research, potatoes at 8cm plantation depth resulted in highest emergence rate in all varieties. By increasing plantation depth from 8cm to 12cm, the emergence percentage of potato plants was reduced. These results suggested that planting depth can affect emergence rates, with shallower depths generally resulting in better emergence (Lubbe, Henry, & Soil, 2019). The practice of shallow planting has been observed to have a significant impact on surface temperature and moisture stress, ultimately influencing the emergence of tubers (Pierret *et al*., 2016). In the event of deep planting, the failure of emergence occurred due to the considerable distance that potato sprouts must traverse in order to emerge from the earth (Semenchuk *et al*., 2016). The findings align with previous studies that have indicated that each potato cultivar had distinct heat unit requirements for the formation of eyes and sprouts (Kwambai *et al*., 2023). Moreover, it has been observed that optimal emergence is contingent upon the availability of sufficient moisture (Stewart *et al*., 2021). The limited availability of water had impact on the absorption of water by the seed tuber, which is crucial for several physiological processes and serves as a medium for biochemical activities within the seed tuber (Bradford, 2017). This includes the facilitation of the transfer of soluble sugars into the developing bud (Shi *et al*., 2021). The percentage of plant emergence was shown to be influenced by the planting depth, with a decrease in plant emergence observed when

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seed tubers were planted at greater depths (Jørgensen, Labouriau, & Olesen, 2019). Additionally, the plantation of seed tubers at a shallow depth may result in tuber greening and moisture stress as a consequence of increased soil surface heat and evaporation (Ilyas, Ayub, & Biology, 2017).

The emergence percentage also depends upon growing variety. Literature advocated the emergence of some potato varieties even at 5cm depth (Chang *et al*., 2016). In present research, Chipsona was observed as the variety with highest emergence percentage at all depths during both phases. In Phase 1, Chipsona exhibited 100% emergence at 8cm and 10cm planting depths, and a high emergence rate of 89% at 12cm depth. In Phase 2, Chipsona achieved 100% emergence at 7 days after sowing and maintained high emergence rates at later stages. Mosika and Kuroda also performed consistently well, with high emergence rates in most cases, especially in Phase 1 at the earlier stages. Sante and Sarpomira showed slightly lower emergence rates compared to Chipsona, Mosika, and Kuroda, but still maintained relatively good results. Asterix consistently had the lowest emergence rates across all phases and planting depths as shown in figure 1.

Among both phases, data regarding 2019 in Kasur region was observed superior than 2020 (Lahore). The observed rise in emergence percentage in 2019 (Kasur) may be attributed to the existing good meteorological conditions characterized by enhanced precipitation and optimal temperatures throughout that duration. The heightened level of soil moisture content performed a significant effect in the dissolution of nutrients and their subsequent absorption, hence exerting a beneficial influence on the emergence percentage (Scavo *et al*., 2022). Moreover, in 2020, frost was observed at night during first week of sowing that subsequently affected the emergence rate of tubers.

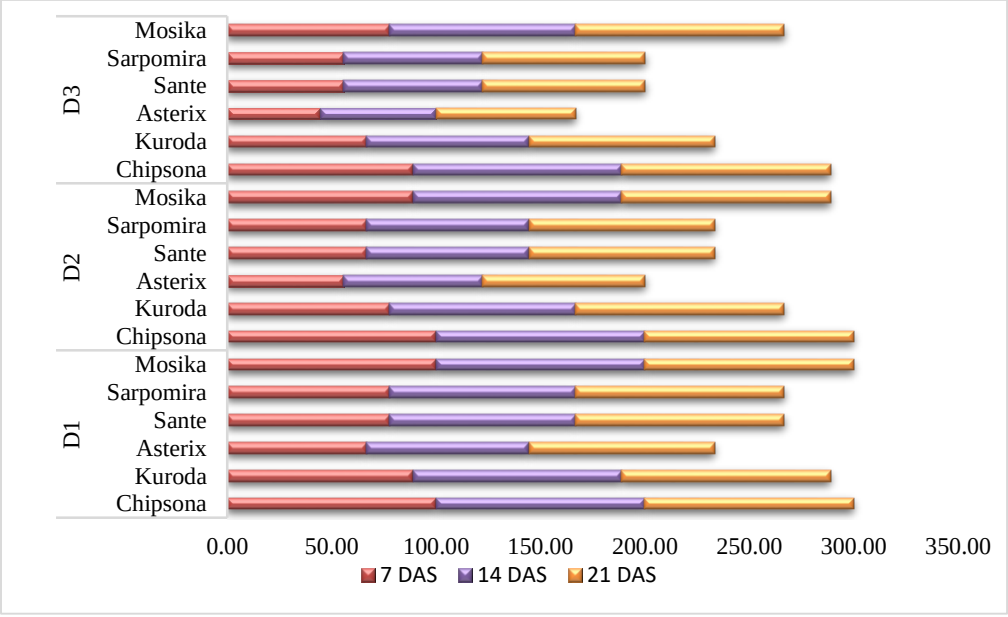

Figure 1: Impact of planting depth on emergence percentage potato varieties after 7, 14 and 21 days of sowing

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Table 1: Impact of planting depth on emergence percentage potato varieties after 7, 14 and 21 days of sowing

Variety	Depth	Phase 1			Phase 2		
		7DAS	14DAS	21DAS	7DAS	14DAS	21DAS
Chipsona	8cm	100 ± 0	100 ± 0.0	100 ± 0.0	100 ± 0.0	100 ± 0.0	100 ± 0.0
	10cm	100 ± 0	100 ± 0.0	100 ± 0.0	89 ± 0.0	100 ± 0.0	100 ± 0.0
	12 cm	89 ± 0.3	100 ± 0.0	100 ± 0.0	78 ± 0.0	89 ± 0.3	100 ± 0.0
Kuroda	8cm	89 ± 0.4	100 ± 0.0	100 ± 0.0	78 ± 0.3	89 ± 0.3	100 ± 0.0
	10cm	78 ± 0.5	89 ± 0.3	100 ± 0.0	56 ± 0.4	67 ± 0.4	78 ± 0.3
	12cm	67 ± 0.5	78 ± 0.4	89 ± 0.3	56 ± 0.4	67 ± 0.5	78 ± 0.4
Asterix	8cm	67 ± 0.5	78 ± 0.4	89 ± 0.3	56 ± 0.5	67 ± 0.5	78 ± 0.4
	10cm	56 ± 0.5	67 ± 0.5	78 ± 0.4	44 ± 0.5	56 ± 0.5	67 ± 0.5
	12cm	44 ± 0.4	56 ± 0.5	67 ± 0.5	33 ± 0.3	44 ± 0.5	56 ± 0.5
Sante	8cm	78 ± 0.5	89 ± 0.3	100 ± 0.0	67 ± 0.4	78 ± 0.4	89 ± 0.3
	10cm	67 ± 0.5	78 ± 0.4	89 ± 0.3	56 ± 0.5	67 ± 0.5	78 ± 0.4
	12cm	56 ± 0.4	67 ± 0.5	78 ± 0.4	44 ± 0.3	56 ± 0.5	67 ± 0.5
Sarpomira	8cm	78 ± 0.5	89 ± 0.3	100 ± 0.0	67 ± 0.4	78 ± 0.4	89 ± 0.3
	10cm	67 ± 0.5	78 ± 0.4	89 ± 0.3	56 ± 0.5	67 ± 0.5	78 ± 0.4
	12cm	56 ± 0.0	67 ± 0.5	78 ± 0.4	44 ± 0.0	56 ± 0.5	67 ± 0.5
Mosika	8cm	100 ± 0.3	100 ± 0.0	100 ± 0.0	89 ± 0.0	100 ± 0.0	100 ± 0.0
	10cm	89 ± 0.4	100 ± 0.0	100 ± 0.0	78 ± 0.3	89 ± 0.3	100 ± 0.0
	12cm	78 ± 0.0	89 ± 0.3	100 ± 0.0	67 ± 0.0	78 ± 0.4	89 ± 0.3

Seedling Vigour

The plant vigor score was recorded after 60 days of planting through visual observations according to 1 to 4 scale. Plants having strong stem with tall seedling and healthy leaves was assumed as excellent thus coded as “4”. The plant that showed good and moderate vigor was recorded as 3 and 2 respectively. Lastly, the plant with stunted growth, small seedling with weak stem was recoded as poor thus given the code “1” following (Wooster & Farooq, 1995). The planting depth of potato seedlings had a significant impact on their vigour after 60 days of sowing as shown in table 2.

The depth of 10cm was observed as optimal depth for achieving good vigor without affecting tuber quality. This may happen due to the reason that shallow planting (8cm) depth may not had covered the tubers that resulted in exposure to direct sunlight, which lead towards tuber greening (Nebiyu, Derbew, & Fanos, 2015). The depth of 10cm resulted in higher vigor scores, indicating better growth and development may be due to the reason that it allowed the tubers to establish proper root systems and provided them with sufficient moisture and nutrients (Gonzalez, Postma, & Wissuwa, 2021).

The roots were able to access the necessary resources in the soil, resulting in strong and vigorous seedlings (Paez-Garcia *et al*., 2015). Planting potato seedlings deep had negative effects on their vigor (Mbiyu *et al*., 2018). Deep planting restricted the growth of the potato tubers, making it difficult for the shoots to emerge from the soil surface (Mhango, Harris, Green, & Monaghan, 2021). This lead to delayed emergence and slower growth of the plants. The vigor of seedlings also depends upon the variety used (Rajabi Dehnavi, Zahedi, Ludwiczak, Cardenas Perez, & Piernik, 2020).

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Chipsona consistently exhibited the highest vigor scores across both phases and different planting depths, indicating its suitability for optimal growth in various conditions. Mosika, Kuroda, Sante and Sarpomira followed it while Asterix consistently showed the lowest vigor score as shown in fig 2.

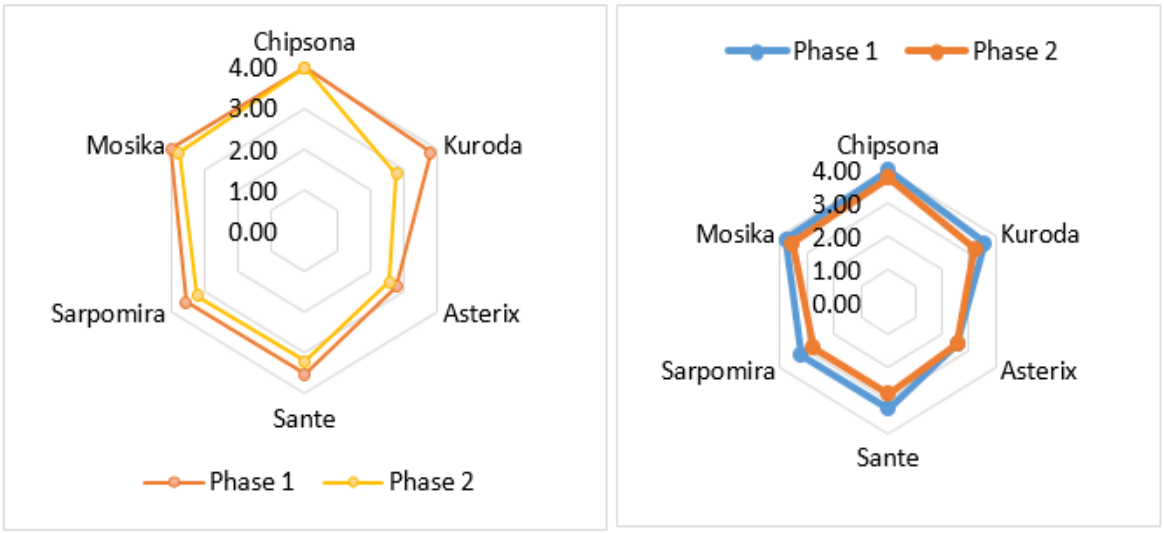

Figure 2: Impact of 8cm & 10cm depth on vigor score of potato varieties during phase 1 and 2

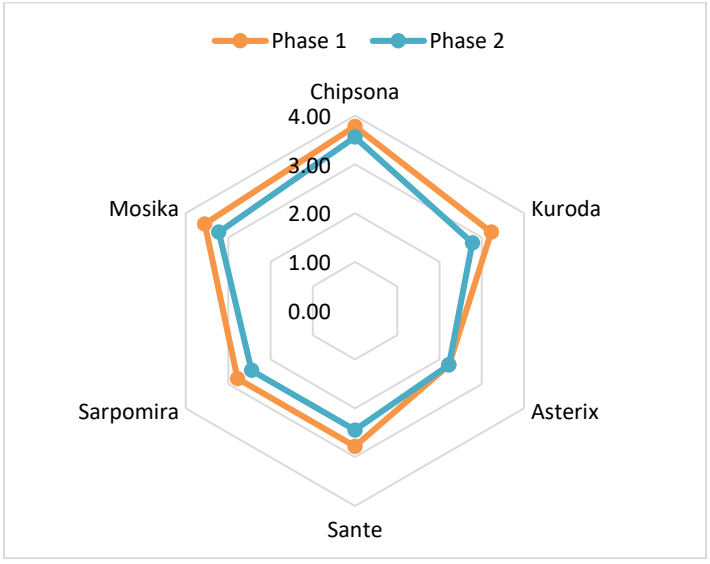

Figure 3: impact of 12cm planting depth on vigor score of potato varieties during phase 1 and 2

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Table 2: Effect of planting depth on vigor score of potato seedlings

Variety	Depth	Phase 1	Phase 2
		Vigor Score	Vigor Score
Chipsona	8cm	4.00 ± 0.0	4.00 ± 0.0
	10cm	4.00 ± 0.0	3.78 ± 0.4
	12cm	3.78 ± 0.4	3.78 ± 0.7
Kuroda	8cm	3.78 ± 0.4	3.22 ± 0.4
	10cm	3.56 ± 0.7	3.22 ± 1
	12cm	3.22 ± 1	3.78 ± 1.1
Asterix	8cm	3.22 ± 1	3.78 ± 1.1
	10cm	2.78 ± 1.1	2.78 ± 1.2
	12cm	2.44 ± 1.2	2.44 ± 1.1
Sante	8cm	3.56 ± 0.7	2.78 ± 1
	10cm	3.22 ± 1	2.78 ± 1.1
	12cm	2.78 ± 1.1	3.56 ±1.2
Sarpomira	8cm	3.56 ± 0.7	3.56 ± 1
	10cm	3.22 ± 1	2.78 ± 1.1
	12cm	2.78 ± 1.1	2.11 ± 1.2
Mosika	8cm	4.00 ± 0.0	2.44 ± 0.4
	10cm	3.78 ± 0.4	2.44 ± 0.7
	12cm	3.56 ± 0.7	3.22 ± 1

Yield/plant

The effect of different planting depth (D_1, D_2, D_3) and various levels of fertilizer (F_1, F_2 and F_3) on average yield of tubers per plant was calculated as shown in table 3. An increase of depth from 8cm to 12cm cause the plants to develop large size tubers with reduced number of tubers per plant. The presented results suggested that depth of 10cm consistently resulted in the highest average tuber weight and number of tubers per plant for all varieties and fertilizer treatments. Depth of 8cm followed closely behind, while a depth of 12cm exhibited the lowest results as shown in figure 4. An increase in yield in response to increasing the depth of planting seed tubers from 8 to 10 cm may be attributed to the provision of sufficiently loose soil for the nourishment of seedlings through the good proliferation of roots, resulting in the optimum emergence of sprouts above the soil surface and their subsequent growth (Gray & Brady, 2016).

Table 3: Mean effect of depth and fertilizer on potato yield per plant

Planting Depth	Varieties	Phase 1 (Kasur)			Phase 2 (Lahore)		
		F1	F2	F3	F1	F2	F3
8cm	Chipsona	4371±58	4549±71	4351±35	1857±49	2025±16	1914±57
	Kuroda	3351±43	3596±52	3346±64	1425±33	1484±59	1388±49
	Asterix	371±24	486±41	428±39	290±12	385±25	366±29
	Sante	1177±59	1291±35	1197±25	683±16	734±26	688±39
	Sarpomira	1004±57	1113±35	978±25	539±27	591±20	560±36
	Mosika	2329±42	2437±48	2201±48	1021±18	1045±16	975±45
10cm	Chipsona	4916±55	5122±30	4799±58	2149±43	2270±39	1991±43
	Kuroda	3695±18	3864±41	3717±35	1395±71	1489±34	1440±35
	Asterix	587±24	665±22	554±20	414±18	467±20	477±22
	Sante	1405±45	1552±55	1506±50	784±37	860±13	806±49

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	Sarpomira	1217±51	1357±38	1298±27	625±22	726±31	643±24
	Mosika	2543±21	2708±29	2604±42	1296±44	1292±21	1214±54
12cm	**Chipsona**	5203±81	5463±35	5356±58	2390±23	2457±37	2333±72
	Kuroda	4085±62	4179±39	4028±82	1690±84	1717±22	1597±24
	Asterix	745±31	857±29	815±41	520±13	562±33	511±23
	Sante	1677±32	1876±58	1788±49	893±28	1063±23	841±49
	Sarpomira	1548±32	1698±24	1689±57	789±24	904±30	800±38
	Mosika	2828±31	2985±22	2889±55	1277±18	1418±38	1251±47

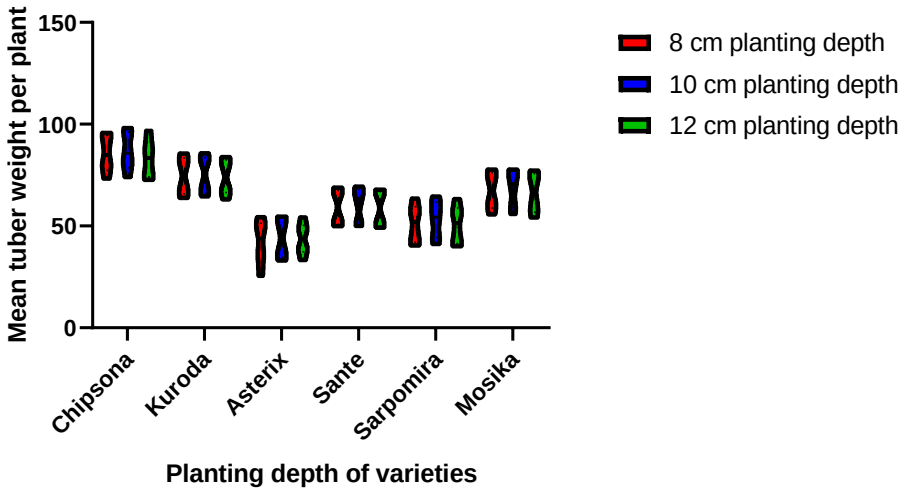

Figure 4: Effect of planting depth on yield of potato varieties

Among the fertilizer treatments, F_2 resulted in higher marketable yield compared to F_1 and F_3. The yield parameter has a direct relationship with variety of tuber used. High yielding varieties exhibits more tuber production than low yielding ones (Muleta & Aga, 2019). From the current experiment, Chipsona can be marked as high yielding and superior variety among all other varieties. Kuroda and Mosika closely followed it. Sante and Sarpomira also exhibited good results but their performance was less as compare to Kuroda and Mosika. However, Asterix exhibited least results.

CONCLUSION

The data pertaining the depth of sowing revealed that the depth of 10cm remained best for gaining maximum emergence, vigor and yield, regardless of variety and fertilizer treatment. Depth of 8cm followed it while 12cm exhibited least results. Among all investigated treatment plan, F2 can be graded as excellent for acquiring maximum yield regardless of depth and variety. Among both phases, the results of first phase was superior than the second one. Chipsona can be marked as superior variety following by Mosika, Kuroda, Sante, Sarpomira and Asterix. Statistically, all the varieties in both phases exhibited highly significant results.

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References

1) Al-Shareefi, M. J., Abbass, J. A., & Abdulhussein, M. A. A. J. I. J. A. S. S. (2020). Effect of light sources and culture systems on micro tubers production of potato (Solanum tuberosum L.) In Vitro. *16*(2), 679-686.

2) Ali, S. W., Nawaz, A., Irshad, S., Khan, A. A. J. J. o. H. E., & Design. (2015). Potato waste management in Pakistan's perspective. *13*, 100-107.

3) Bradford, K. J. (2017). Water relations in seed germination. In *Seed development and germination* (pp. 351-396): Routledge.

4) Chang, D. C., Cho, J. H., Jin, Y. I., Im, J. S., Cheon, C. G., Kim, S. J., & Yu, H.-S. J. F. C. R. (2016). Mulch and planting depth influence potato canopy development, underground morphology, and tuber yield. *197*, 117-124.

5) Dev, A., Kumar, S., Kumar, D., Patel, V. K., Kumar, A., Sahu, R. K., & Singh, P. (2020). The Effect of Integrated Nutrient Management (INM) and Zn Fertilization on Yield of Potato. *Int. J. Curr. Microbiol. App. Sci, 9*(4), 1518-1526.

6) Devaux, A., Goffart, J.-P., Kromann, P., Andrade-Piedra, J., Polar, V., & Hareau, G. J. P. R. (2021). The potato of the future: opportunities and challenges in sustainable agri-food systems. *64*(4), 681-720.

7) Gonzalez, D., Postma, J., & Wissuwa, M. J. F. i. P. S. (2021). Cost-benefit analysis of the upland-rice root architecture in relation to phosphate: 3D simulations highlight the importance of S-type lateral roots for reducing the pay-off time. *12*, 641835.

8) Gray, S. B., & Brady, S. M. J. D. b. (2016). Plant developmental responses to climate change. *419*(1), 64-77.

9) Hassan, S. Z., Jajja, M. S. S., Asif, M., & Foster, G. J. M. D. (2021). Bringing more value to small farmers: a study of potato farmers in Pakistan. *59*(4), 829-857.

10) Ilyas, M., & Ayub, G. (2017). Role of planting depth and mulching on growth and yield components of autumn potato crop sown at different dates. *Pure and Applied Biology (PAB), 6*(4), 1436-1449.

11) Ilyas, M., Ayub, G. J. P., & Biology, A. (2017). Role of planting depth and mulching on growth and yield components of autumn potato crop sown at different dates. *6*(4), 1436-1449.

12) Jørgensen, M. S., Labouriau, R., & Olesen, B. J. P. o. (2019). Seed size and burial depth influence Zostera marina L.(eelgrass) seed survival, seedling emergence and initial seedling biomass development. *14*(4), e0215157.

13) Jurayev, A., Jurayev, U., Atamurodov, B., Sobirov, K., & Najmiddinov, M. J. W. o. S. I. S. R. J. (2022). The effectiveness of intensive cultivation of potatoes in conditions of saline soils. *3*(6), 1853-1859.

14) Kot, A. M., Pobiega, K., Piwowarek, K., Kieliszek, M., Błażejak, S., Gniewosz, M., & Lipińska, E. J. P. R. (2020). Biotechnological methods of management and utilization of potato industry waste—a review. *63*, 431-447.

15) Kwambai, T. K., Griffin, D., Nyongesa, M., Byrne, S., Gorman, M., & Struik, P. C. J. P. R. (2023). Dormancy and physiological age of seed tubers from a diverse set of potato cultivars grown at different altitudes and in different seasons in Kenya. 1-25.

16) Lubbe, F. C., Henry, H. A. J. P., & Soil. (2019). The cost of depth: frost avoidance trade-offs in herbaceous plants. *444*, 213-224.

17) Mbiyu, M. W., Lungâ, C., Otieno, S. A., Nyongesa, M. W., Muchui, M. N., & Ogemma, J. N. J. A. J. o. A. R. (2018). Performance of five potato varieties with regards to growth and production of mini-tubers under an aeroponic system in central highlands of Kenya. *13*(8), 366-378.

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ISSN (Online):0493-2137
E-Publication: Online Open Access
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DOI: 10.5281/zenodo.10223959

18) Memon, A. (2017). Potato: An important food crop in Pakistan. *Dean FBMS*, 15.

19) Mhango, J. K., Harris, E. W., Green, R., & Monaghan, J. M. J. R. S. (2021). Mapping potato plant density variation using aerial imagery and deep learning techniques for precision agriculture. *13*(14), 2705.

20) Muleta, H. D., & Aga, M. C. J. J. o. P. S. (2019). Role of nitrogen on potato production: a review. *7*(2), 36-42.

21) Nebiyu, A., Derbew, B., & Fanos, T. J. J. B. (2015). Effect of planting depth and time of earthing-up on potato (solanum tuberosum L.) yield and yield components at Jimma university college of agriculture and veterinary medicine, South west Ethiopia. *15*, 61-78.

22) Paez-Garcia, A., Motes, C. M., Scheible, W.-R., Chen, R., Blancaflor, E. B., & Monteros, M. J. J. P. (2015). Root traits and phenotyping strategies for plant improvement. *4*(2), 334-355.

23) Pierret, A., Maeght, J.-L., Clément, C., Montoroi, J.-P., Hartmann, C., & Gonkhamdee, S. J. A. o. b. (2016). Understanding deep roots and their functions in ecosystems: an advocacy for more unconventional research. *118*(4), 621-635.

24) Rajabi Dehnavi, A., Zahedi, M., Ludwiczak, A., Cardenas Perez, S., & Piernik, A. J. A. (2020). Effect of salinity on seed germination and seedling development of sorghum (Sorghum bicolor (L.) Moench) genotypes. *10*(6), 859.

25) Scavo, A., Fontanazza, S., Restuccia, A., Pesce, G. R., Abbate, C., & Mauromicale, G. J. A. f. S. D. (2022). The role of cover crops in improving soil fertility and plant nutritional status in temperate climates. A review. *42*(5), 93.

26) Semenchuk, P. R., Gillespie, M. A., Rumpf, S. B., Baggesen, N., Elberling, B., & Cooper, E. J. J. E. R. L. (2016). High Arctic plant phenology is determined by snowmelt patterns but duration of phenological periods is fixed: an example of periodicity. *11*(12), 125006.

27) Shi, J., Zhou, H., Liu, X., Wang, N., Xu, Q., & Yan, G. J. P. (2021). Correlation analysis of the transcriptome and metabolome reveals the role of the flavonoid biosynthesis pathway in regulating axillary buds in upland cotton (Gossypium hirsutum L.). *254*(1), 7.

28) Stewart, S., Kitchen, N., Yost, M., Conway, L. S., Carter, P. J. A., Geosciences, & Environment. (2021). Planting depth and within-field soil variability impacts on corn stand establishment and yield. *4*(3), e20186.

29) Thornton, M. (2020). Potato growth and development. In *Potato Production Systems* (pp. 19-33): Springer.

30) TrendEconomy. (2020). *Annual International Trade Statistics by Country (HS02)*. Retrieved from https://trendeconomy.com/data/h2/Pakistan/0701

31) Visvanathan, R., Jayathilake, C., Chaminda Jayawardana, B., Liyanage, R. J. J. o. t. S. o. F., & Agriculture. (2016). Health-beneficial properties of potato and compounds of interest. *96*(15), 4850-4860.

32) Wooster, P., & Farooq, K. J. P. S. P. D. P., PARC Islamabad, Pakistan. (1995). National program of germplasm screening, general instructions for trial and guide to data collection. 24.