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Impact of Seed Sources, Genotypes and Fertilizer Sources on Onion Set Production Potential

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Abstract: Onion is an important commercial vegetable of Pakistan, used daily as culinary item. Its prices are usually low during April-June, the time when Sindh and Punjab crops are available in the market, due to which the growers cannot get a good return from their seasonal crop (May). However, market demand and therefore price is high during the months of November and December. Production and availability of kharif onion crop through sets during this period can pay a good profit. Therefore, this study was carried out at Vegetable Research Area, University of Agriculture Faisalabad; with the aim to determine the set production potential of three onion cultivars *viz.* Red Bone, TI-172 and in comparison with Phulkara; ii) influence of seed source (Magnus Kahl Seeds [MKS] and Government source [Govt.]) on set production of cv. Phulkara; and ii) the effect of two phosphatic fertilizers, diammonium phosphate (DAP) and nitrophos (NP), applied @ 100 g 272.25 ft^{-2}five times at two-week interval on set production of onion cv. Phulkara. Two experiments were conducted for this purpose, which were replicated three times. Results showed that Phulkara (MKS) produced the highest number of sets (1807/45.5 ft^2) while Red Bone produced the lowest number (119). Also, the Phulkara (MKS) had the largest individual (1.9 g) and total (2761.5 g/45.5 ft^2) set weights than that of any experimental cultivars. The application of DAP produced highest number of sets (1187.3/45.5 ft^2) and individual set weight (1.46 g), followed by NP and then control. Our results indicate that the Phulkara (MKS) showed a strong potential in terms of producing a good number and healthier sets. While DAP application to Phulkara (Govt.) produced the highest number of sets having the greatest mean set weight. It was concluded that newly available onion hybrids in the market don't have set production potential. Moreover, seed source has great impact on good quality set production of those cultivars which had been reported to have sets production potential.

Keywords: *Allium cepa* L.; Kharif crop; Phulkara; TI-172; Red Bone; Set formation index

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1. Introduction

Onion (*Allium cepa* L.) is an important commercial vegetable globally as well as in Pakistan, and a good source of income for the small land-holders due to its high return (Ziaf et al., 2019). Various components of onion are rich in bioactive compounds, antioxidants and phytochemicals, which can be used in nutrient supplements, and pharmacological drugs (Kumar et al., 2022; Marrelli et al., 2019; Sagar et al., 2022; Zhao et al., 2021). As the country's population increased, the rate of onion production also has increased (Mahmood et al., 2021; Qazi et al., 2021). According to FAO

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statistics, total onion production in Pakistan reached 2.12 million tons, on an area of 0.15 m ha, at an average yield rate of 15.5 t ha^{-1}, which is quite low if compared with potential yields (FAO, 2018). Few of major reasons of this low productivity in onion are: use of inferior quality seed of limited number of cultivars, inapt production timing and unbalanced fertilization practices which reduce the margin of small-land holders income by increasing cost of production (Anjum et al., 2019; Luqman et al., 2020; Masood et al., 2012; Muhammad et al., 2021).

Production of onion in the country is much higher in rabbi season than the kharif season (Diwivedi and Asat, 2019; Government of Pakistan, 2018a; Singh et al., 2021). So, the rate of onion produced in rabbi season (April-May) falls due to glut in the market (Government of Pakistan, 2018b). While onion is short in the market during November-December and market price is very high (Fatima et al., 2015). If onion crop is ready to harvest during this period, it can give farmers a high return. But onion cannot be raised through seed – seedlings method in Punjab during July-August as the temperature is very high during these months. Production of onion through sets can give a good bulb crop during November-December (Naz and Amjad, 2004). Onion sets are small-size bulbs with diameter 10-35 mm in size (Khokhar, 2008). Their size has a drastic influence on the maturity time and yield of onion (Mousa, 2015). Moreover, improvement in the yield of kharif onion per unit area is possible through the adoption of high set yielding varieties and judicious use of appropriate fertilizer.

Nitrogen and phosphorus are important nutrients for crop production and are required for quantity and quality of sets production (Bezabih and Girmay, 2020; Di Miceli et al., 2022; El-Sherbeny et al., 2022; Negi et al., 2022; Tekeste et al., 2017). Nitrogen is integral part various biological compounds including proteins, enzymes, and vitamins in plants. Moreover, it is main part of chlorophyll (Ata-Ul-Karim et al., 2016; Ata-Ul-Karim et al., 2017; Louarn et al., 2021; Porcar-Castell et al., 2021).

In onion production, efficiency of fertilizer use reported to be low and increased losses of nutrient leaching (Geisseler et al., 2022). Research information regarding potential cultivars except few *i.e.,* Phulkara and Nasarpuri (Cheema et al., 2002) and right source (fertilizer) of N and P for sustainable sets production is insufficient or sporadic. In view of this, current study was carried out to: 1) evaluate set production potential of two commercial hybrids in comparison with cv. Phulkara, the most suitable cv. for set production; 2) compare impact of seed source on set production potential of onion cv. Phulkara; 3) compare the effect of two different sources of N-P fertilizers on set production of onion cv. Phulkara.

2. Materials and Methods

2.1. Experimental site and Experimental details

An experiment was conducted at Vegetable Experimental Area (31°26'N and 73°4'E with an altitude of 182 m), University of Agriculture Faisalabad, Pakistan during 2019. This area has a sub-tropical climate. Monthly averages of air temperature, relative humidity and photoperiod as well as total rainfall on monthly basis were computed (Fig. 1.).

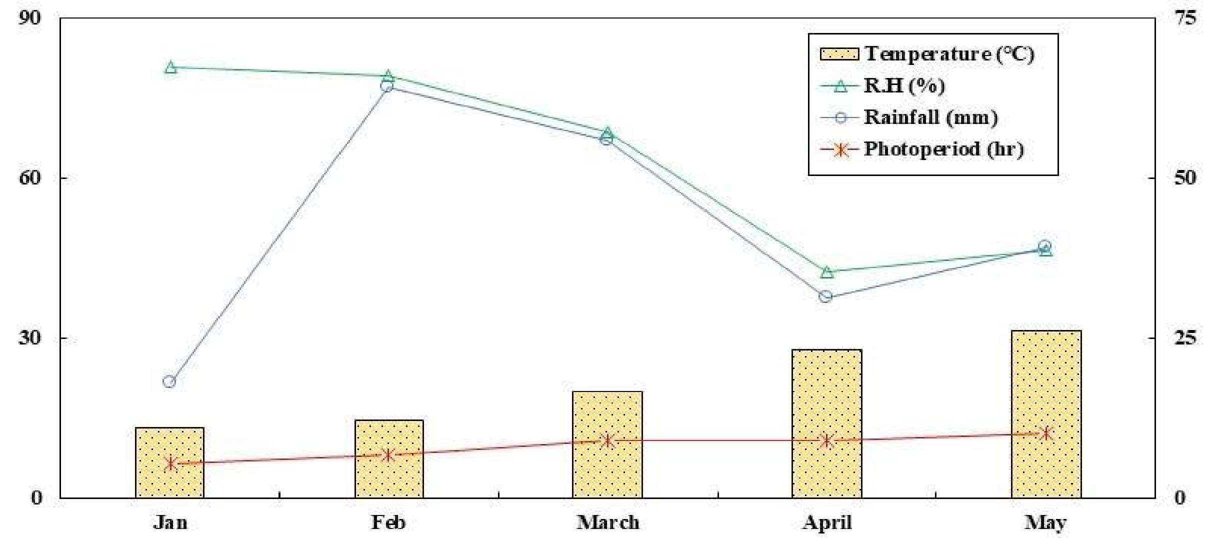

Fig. 1. Monthly averages of temperature, relative humidity, photoperiod, and total rainfall during the period of experiment (2019), at University of Agriculture, Faisalabad, Pakistan.

Before conducting the experiment, three random soil samples were taken from the experimental area at two depths (0-15 and 15-30 cm) and after combining both to make a composite representative sample, soil was analyzed for the initial selected physical and chemical attributes, following Ryan et al. (2012).

Soil texture (Bouyoucos, 1951), pH (McLean, 1982), electrical conductivity (EC) (Richards, 1954), organic matter (Nelson and Sommers, 1982), available phosphorus (Olsen et al., 1954), available potassium (K) (Thomas, 1982) and total nitrogen (N) (Bremner, 1996) were determined **(Table1)**.

Table 1. Pre-sowing soil analysis of the experimental area (January 2019).

Physical properties	
Clay (%)	24
Silt (%)	27
Sand (%)	49
Textural class	Sandy loam
Chemical properties	
Soil pH	8.3
EC (dSm^{-1})	2.05
Organic matter (%)	0.85
Available N (%)	0.075
Available P (mg kg^{-1} soil)	30
Available K (mg kg^{-1} soil)	315

Seed of Phulkara was purchased from Vegetable Research Institute, Ayyub Agricultural Research Institute, Faisalabad, Pakistan while Phulkara from the certified distributor of Magnus Kahl Seeds (MKS, Pakistan) and Red Bone and TI-172 from the distributor of California Valley Seeds.

The study consisted of two experiments *viz.,* 1) comparison of set production potential of two hybrids (Red Bone and TI-172) and onion cv. Phulkara (MKS)and Phulkara (Govt.); 2) comparative effect of two phosphatic fertilizers, DAP and NP, applied (at the rate 100 g 272.25 ft^{-2}) five times through fertigation at two-week interval on onion cultivar Phulkara. Sowing of all experimental cultivars was carried out on Jan 28, 2019, with each cultivar sown on raised beds (length = 6.5 × width = 3.5: Area = 45.5 ft^2). The experiment was replicated three times. The sets were harvested on May 28, 2019.

2.2. Field and Laboratory Measurements

Chlorophyll contents in the leaves of onion seedlings were measured using chlorophyll meter (CCM-200plus, Opti-Sciences, USA). Set diameter was recorded using vernier caliper (IP67, BEAPO Hardware Industrial Company, China) while weight of sets was taken on an electronic scale. Set formation index was calculated from the following formula.

$$Set\ formation\ index = \frac{Bulb\ diameter}{Neck\ diameter}$$

2.3. Statistical analyses: The experimental data obtained was underwent analysis of variance (ANOVA) using analytical software, Statistix 9® (Tallahassee, USA). The comparison between cultivars of onion and phosphatic fertilizers, for observed parameters was made within ANOVA. Fisher's least significant differences (LSD) were used following a significant ($P < 0.05$) F-test.

3. Results

Phulkara (MKS) produced the highest total number of sets (1807), followed by Phulkara (Govt.) (1014) (Table 2). While Red Bone was recorded to produce lowest number of sets (119), statistically like those produced byTI-172 (128) (Table 2). The number of larger sets (1-2 cm) were highest too in Phulkara (292), around two folds of that of Phulkara and 22 folds of that of each hybrid (Table 2) (Fig. 2). Also, the weight of larger sets was greatest in Phulkara (MKS) (1.63), around seven folds of that of Phulkara (Govt.) and 34 folds of that of both experimental hybrids (Table 2).

Table 2. Number and weight of sets produced by onion cultivars.

Onion cultivars	**Number of sets (45.5 ft^{-2})**			**Weight of sets (g45.5 ft^{-2})**		
	Total	**1-2 cm**	**< 1 cm**	**Total**	**1-2 cm**	**< 1 cm**
Phulkara (Govt.)	1014 b	118 b	896 b	1117.5 b	205.5 b	912.0 b
Phulkara (MKS)	1807 a	295 a	1512 a	2761.5 a	1638.3 a	1123.2 a
Red Bone	119 c	16 c	103 c	80.5 c	19.5 c	61.0 c
TI-172	128 c	13 c	115 c	71.3 c	16.9 c	54.4 c
LSD F ($P \leq 0.05$)	**32.95**	**5.40**	**30.12**	**38.7**	**17.67**	**24.27**

Treatment means followed by the same letter are not significantly different.

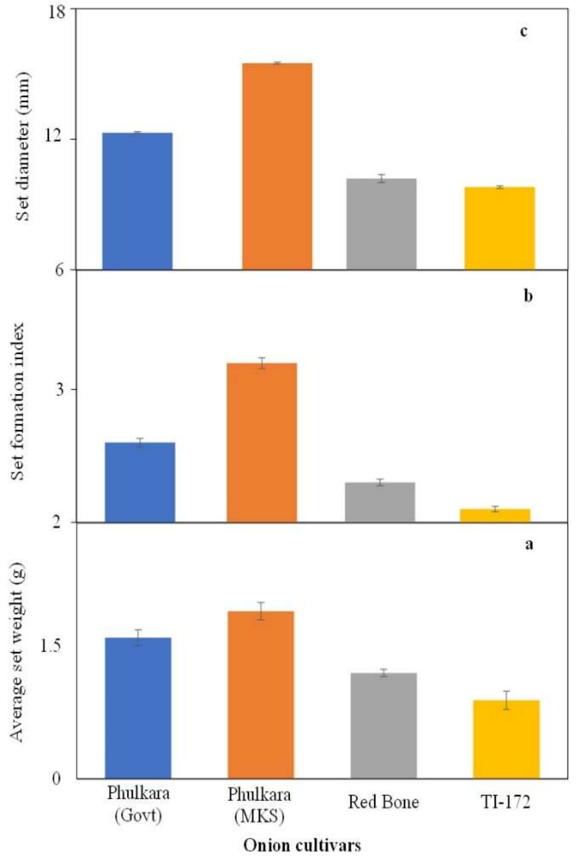

Fig. 2. Genotypic variations in a) average set weight, b) set formation index, and c) set diameter of onion.

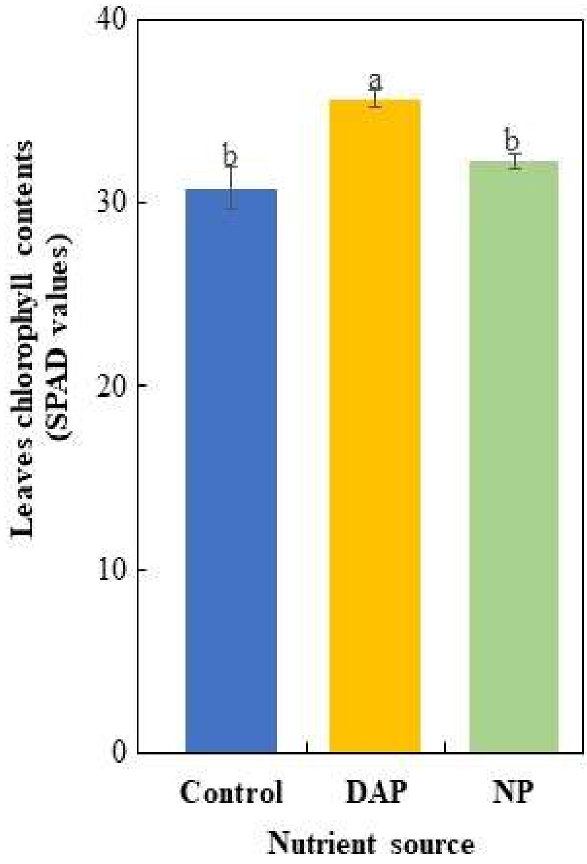

Fig. 3. Comparison of fertilizer sources for chlorophyll contents in leaves of Phulkara (Govt.).

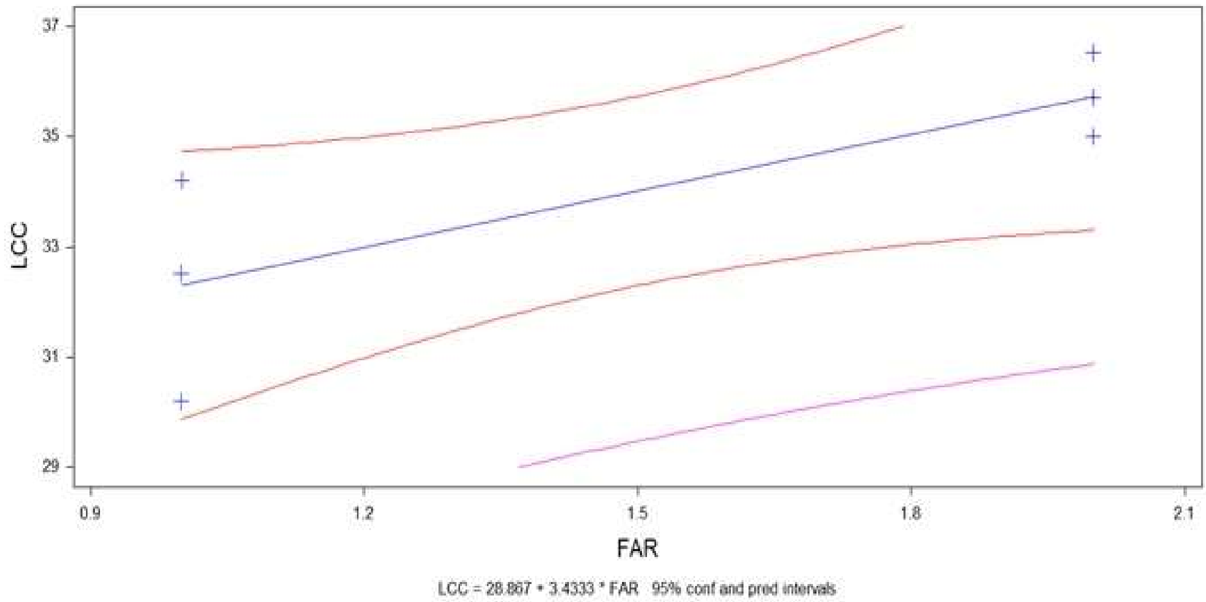

Fig. 4. Simple regression plot obtained for leaves chlorophyll contents (LCC) of onion cv. Phulkara (Govt.) in response to fertilizer application rate (FAR).

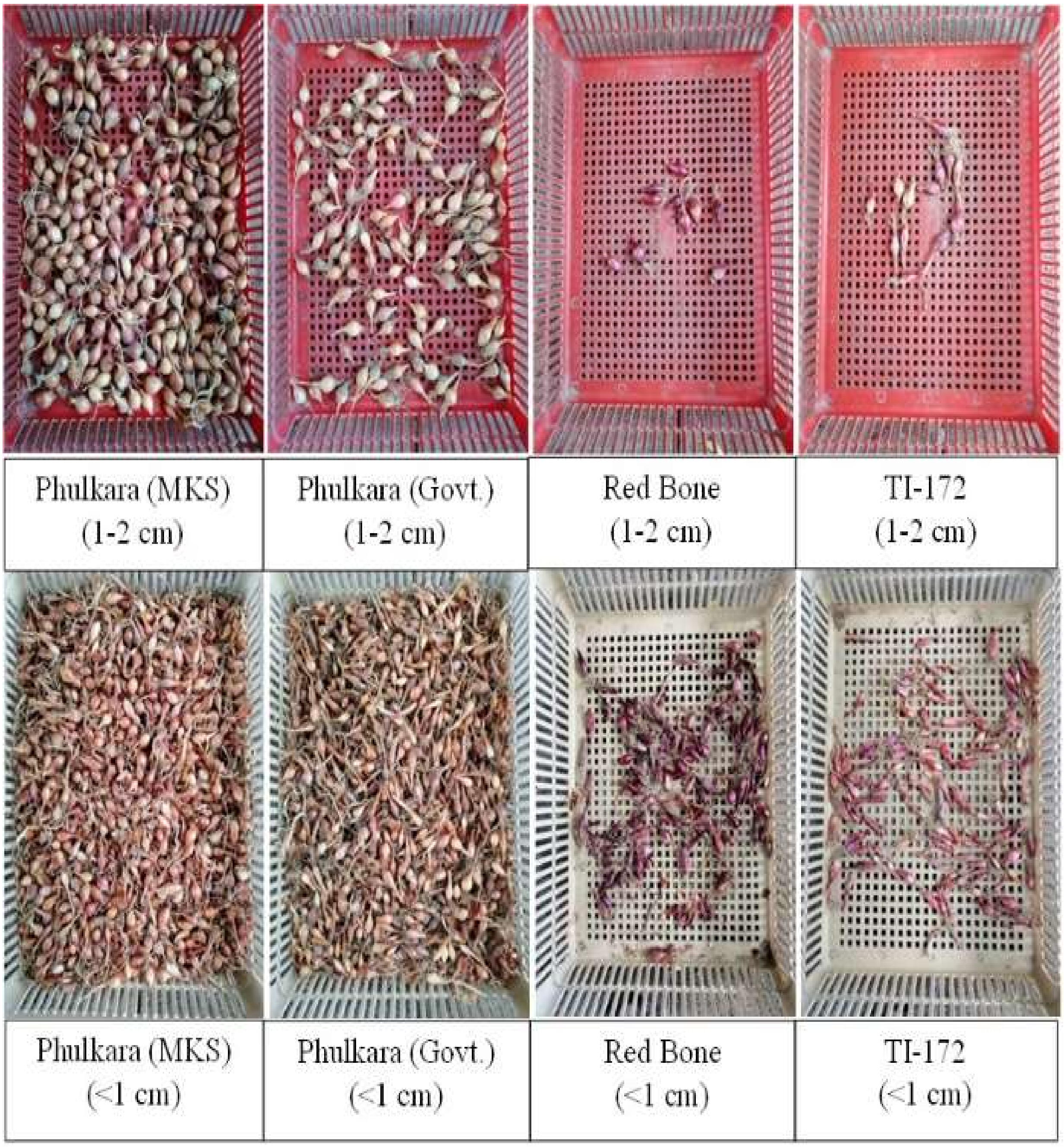

Fig. 5. Two different size ranges of set production observed in experimental onion cultivars

Similarly, set formation index of the Phulkara (MKS) (3.23) was about 26.7% stronger than the Phulkara (Govt.) (2.55), 39.2% stronger than the Red Bone (2.32); and 52.4% stronger than theTI-172 (2.12) (Fig. 2-b). Moreover, the cultivar Phulkara (MKS) also had the largest set diameter (15.5 mm) (Fig. 2-c) as well as individual (1.89 g) (Fig. 2-a) and total (2761.5g) set weights (Table 2) than those of all experimental cultivars. The smallest set diameter (9.8 mm), individual (0.89 g) and total (71.3 g) set weights were observed in TI-172 (Table 2). The application of DAP produced the highest leaves chlorophyll contents (35.7) in onion cv. Phulkara (Govt.), followed by those of NP (32.3) applied seedlings and minimum (30.8) in the control (Fig. 3). Chlorophyll contents increased by 15.9% in DAP applied plot compared to the control. It is evident from the scatter plot (Fig. 4) that as the fertilization rate increases, chlorophyll contents tend to increase.

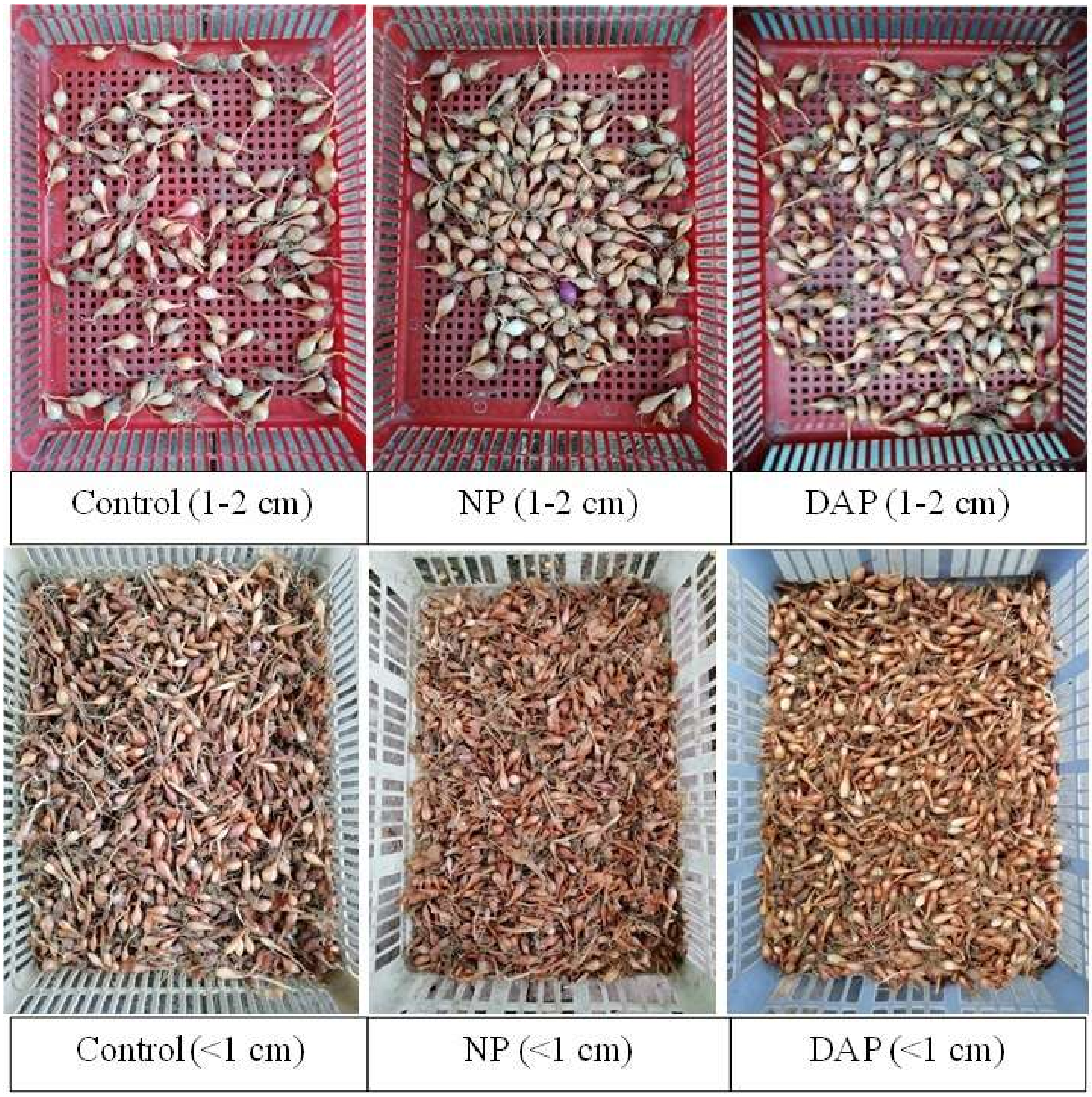

Fig. 6. Sets of Phulkara (Govt.) in response to different nutrient sources.

The maximum total number of sets (1187.3) and individual (1.46 g) and total (1262.0 g) set weights were also recorded in the DAP applied plot while the lowest number of sets (1164.6) and individual (1.33 g) and total (1237.7 g) set weights in the untreated control (Table 3) (Fig. 5, 6). The set diameter and set formation index remained unaffected by the fertilizer sources (Table 3).

4. Discussion

The results of this study demonstrated that Phulkara (MKS) produced the highest total number and larger sets (1-2 cm size) due to strong set formation index. The Phulkara (MKS) was found to have about 78.2% more total number offset sand two folds increase in larger sets than the Phulkara (Govt.). While, the Phulkara (MKS) had an approximately 14 folds increase in total number of sets in comparison to both hybrids TI-172 and Red Bone. Similarly, the Phulkara (MKS) had an 18.7% increase in individual and two folds increase in total set weight compared to the Phulkara (Govt.), while had a 58.3% higher individual set weight and 34 folds higher total set weight compared to TI-172. The results are in agreement with the findings of Cheema et al. (2003) and Ansari (2007) who revealed significant response of onion cultivars to the set production. Highest set formation index in

Phulkara (MKS) seedlings might be due to their ideal photoperiod requirement for bulbing. While slightly longer photoperiod requirement of experimental onion hybrids might have reverted the seedlings to leaf growth and they failed to produce a good quantity and size of sets. Pertaining to the nutrition study, increment in the fertilizer rate from 0 in the control to 100 g in the DAP applied plot resulted in progressive increase in the number and weight of sets. Though the sets number exceeds by almost 1% in DAP applied plot compared to the NP fertilized and 2.0% compared to the control. The weight of sets in DAP applied plot was 1.6% greater than that of NP applied plot and 5% greater compared to the control. Our results reflect the findings of Nasreen et al. (2007), Ali et al. (2016) and Tekeste et al. (2018) who observed significant increase regarding onion bulb yield in response to N and P fertilization. The highest yield in DAP applied plot might be due to positive influence of the balanced supply of N and P to the seedlings which enhanced the synthesis of proteins, enzymes, chlorophyll contents and carbohydrates and hence enhanced the sets production. However, the fertilizer source had no effect on the set size. Similar result was found by Azam et al. (2013) who observed non-significant difference between bulbs diameter obtained under different nutrition regimes.

5. Conclusion

Seed quality affects sets production as indicated by higher number of good quality sets produced from Phulkara MKS compared to Phulkara (Govt.). Therefore, cultivar Phulkara (MKS) has a strong potential to produce a good yield of quality sets and is recommended for raising kharif crop, while Phulkara (Govt.) needs to be purified because it is losing its characteristics. Moreover, DAP application five times @100 g 272.25 ft^{-2} helped to improve quality of onion sets and is recommended for onion set production on moderately fertile soils.

Competing Interest Statement: All authors have read and agreed to the published version of the manuscript.

List of Abbreviations: DAP = Diammonium phosphate; NP = Nitrophos; FAO = Food and Agriculture Organization; Govt = Pakistan Government; MKS = Magnus and Kahl Seeds, Australia; ANOVA = Analysis of variance; LSD = Least significant difference test.

Author's Contribution: **Conceptualization**, M.W.H. and K.Z.; **Data curation**, R.A. and A.U.M.; **Formal analysis**, M.W.H., K.Z. and M.M.J.; **Funding acquisition**, A.U.M., M.A. and B.E.B.; **Investigation and Methodology**, M.W.H., K.Z. and M.A.G.; **Resources**, Y.M. and C.M.A.; **Validation**, M.W.H. and K.Z.; **Visualization**, A.U.M.; **Writing – original draft**, M.W.H. and R.R.; **Writing – review & editing**, K.Z.

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References

Ali, J., A. Rab, H. Muhammad, M. Ali, A. Rashid, A. Shakoor, A. Khan, J. Khan, A. Jamal and Hamid Khan. 2016. Effect of sowing dates and phosphorus levels on growth and bulb production of Onion. Pure Appl. Biol. 5: 406-417.

Anjum, M., H. Muhammad, R. Balal and R. Ahmad. 2019. Performance of two onion (*Allium cepa* L.) cultivars under two different planting systems in calcareous soil. J. Hort. Sci. Technol. 2: 54-59.

Ansari, N.A. 2007. Effect of density, cultivars and sowing date on onion sets production. Asian J. Plant Sci. 6: 1147-1150.

Ata-Ul-Karim, S.T., Q. Cao, Y. Zhu, L. Tang, M.I.A. Rehmani and W. Cao. 2016. Non-destructive Assessment of Plant Nitrogen Parameters Using Leaf Chlorophyll Measurements in Rice. Front. Plant Sci. 7: 1829.

Ata-Ul-Karim, S.T., Y. Zhu, Q. Cao, M.I.A. Rehmani, W. Cao and L. Tang. 2017. In-season assessment of grain protein and amylose content in rice using critical nitrogen dilution curve. Eur. J. Agron. 90: 139-151.

Azam, M.G., M. Islam, M.A. Gulandaz and J.A. Mahmud. 2013. Effect of different source of nutrients on the performance, growth and quality of summer onion. J. Environ. Sci. Nat. Resour. 6: 159-162.

Bezabih, T.T. and S. Girmay. 2020. Nutrient use efficiency and agro-economic performance of onion (*Allium cepa* L.) under combined applications of N, K and S nutrients. Vegetos 33: 117-127.

Bouyoucos, G.S. 1951. Recalibration of the hydrometer methods for making mechanical analysis of soil. Agron. J. 43: 434-438.

Bremner, J.M. 1996. Nitrogen-total. p. 1085-1121. In: J.M. Bartels and J.M. Bigham (Eds.). Methods of Soil Analysis, Part III. American Society of Agronomy, Madison, WI, USA.

Cheema, K.L., A. Saeed and M. Ahmad. 2002. Autumn crop production through sets in eight onion cultivars. Int. J. Agric. Biol. 4: 547-549.

Di Miceli, G., D. Farruggia, N. Iacuzzi, S. Bacarella, S. La Bella and B.B. Consentino. 2022. Planting Date and Different N-Fertilization Rates Differently Modulate Agronomic and Economic Traits of a Sicilian Onion Landrace and of a Commercial Variety. Horticulturae 8: 454.

Dwivedi, B. and K. Asati. 2019. Effect of PGRs and their methods of application on yield, quality and economics of kharif onion (*Allium cepa* L.) cv. Agri found Dark Red. Pharma Innov. J. 8(10):70-73.

El-Sherbeny, T.M.S., A.M. Mousa and E.-S.R. El-Sayed. 2022. Use of mycorrhizal fungi and phosphorus fertilization to improve the yield of onion (*Allium cepa* L.) plant. Saudi J. Biol. Sci. 29: 331-338.

FAOSTAT. 2018. Food and Agriculture Organization of the United Nations database. (Available at: http://faostat.fao.org/).

Fatima, A., S. Abid and S. Naheed. 2015. Trends in wholesale prices of onion and potato in major markets of Pakistan: a time series analysis. Pak. J. Agri. Res. 28: 152-158.

Geisseler, D., R.S. Ortiz and J. Diaz. 2022. Nitrogen nutrition and fertilization of onions (Allium cepa L.)–A literature review. Sci. Horti. 291: 110591.

Government of Pakistan. 2018a. Economic Survey of Pakistan. Economic Adviser's Wing, Finance Division, Government of Pakistan, Islamabad.

Government of Pakistan. 2018b. Ministry of National Food Security and Research, Agricultural Statistics, Economic Wing, Government of Pakistan, Islamabad.

Khokhar, K.M. 2008. Effect of set-size and planting time on the incidence of bolting, bulbing, and seed yield in two onion cultivars. J. Hort. Sci. Biotechnol. 83: 481-487.

Kumar, M., M.D. Barbhai, M. Hasan, S. Punia, S. Dhumal, Radha, et al. 2022. Onion (*Allium cepa* L.) peels: A review on bioactive compounds and biomedical activities. Biomed. Pharmacotherapy. 146: 112498.

Louarn, G., L. Bedoussac, N. Gaudio, E.-P. Journet, D. Moreau, E. Steen Jensen, et al. 2021. Plant nitrogen nutrition status in intercrops– a review of concepts and methods. Eur. J. Agron. 124: 126229.

Luqman, L., M. Ilyas, I.A. Khan and T. Bakht. 2020. Influence of sowing orientation and intercropping of chilies on onion yield and its associated weeds in Peshawar, Pakistan. Pak. J. Bot. 52: 95-100.

Mahmood, N., M.A. Muazzam, M. Ahmad, S. Hussain and W. Javed. 2021. Phytochemistry of *Allium cepa* L. (Onion): An overview of its nutritional and pharmacological importance. Sci. Inq. Rev. 5: 41-59.

Marrelli, M., V. Amodeo, G. Statti and F. Conforti. 2019. Biological properties and bioactive components of *Allium cepa* L.: Focus on potential benefits in the treatment of obesity and related comorbidities. Molecules. 24: 119.

Masood, A., N. Ellahi and Z. Batool. 2012. Causes of low agricultural output and impact on socio-economic status of farmers: A case study of rural Potohar in Pakistan. Inter. J. Basic Appl. Sci. 1: 343-351.

Mousa, M.A.A. 2015. Control of doubling and early bolting in bulbs of onion genotypes by sizes of sets and irrigation systems. Life Sci. J. 12:61-74.

Muhammad, T., M. Amjad, S. Hayat, H. Ahmad and S. Ahmed. 2021. Influence of nursery sowing dates, seedling age and nitrogen levels on bulb quality and marketable yield of onion (*Allium cepa* L.). Pure Appl. Biol. 5: 223-233.

Nasreen, S., M.M. Haque, M.A. Hossain and A.T.M. Farid. 2007. Nutrient uptake and yield of onion as influenced by nitrogen and sulphur fertilization. Bangladesh J. Agric. Res. 32: 413-420.

Naz, S. and M. Amjad. 2004. Production potential of diverse onion genotypes raised through sets. Pak. J. Agri. Sci. 41: 141-143.

Negi, M., J.C. Sharma, Y.R. Shukla, A. Chauhan, S. Sharma and K. Sharma. 2022. Comparative assessment of different nutrient sources on growth, yield and nutrient uptake by onion (*Allium cepa* L.). J. Plant Nutr. 45: 1516-1522.

Nelson, D.W. and L.E. Sommers. 1982. Organic matter. p. 574-579. In: A.G. Norman (ed.). Methods of Soil Analysis Part II. Chemical and microbiological properties, 2nd Ed. American Society of Agronomy, Madison, WI, USA.

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA, U.S. Government Printing Office, Washington, D.C., USA.

Porcar-Castell, A., Z. Malenovský, T. Magney, S. Van Wittenberghe, B. Fernández-Marín, F. Maignan, et al. 2021. Chlorophyll a fluorescence illuminates a path connecting plant molecular biology to Earth-system science. Nat. Plants. 7: 998-1009.

Qazi, M.A., M.N. Iqbal, M. Sadiq, F. Umar, K.M. Mughal, M. Khalid, et al. 2021. Phosphorus fertilizer response to onion (*Allium cepa* L.) yield in Punjab, Pakistan. Adv. Life Sci. 8: 149-153.

Richards, L.A. 1954. Diagnosis and Improvement Saline and Alkaline Soils. USDA, Washington, D.C., USA.
Ryan, J., G. Estefan and A. Rashid. 2012. Soil and Plant Analysis Laboratory Manual. 2nd Ed. ICARDA, Aleppo, Syria.
Sagar, N.A., S. Pareek, N. Benkeblia and J. Xiao. 2022. Onion (*Allium cepa* L.) bioactives: Chemistry, pharmacotherapeutic functions, and industrial applications. Food Front. 3: 380-412.
Singh, R.K., M. Meena, S.P. Singh, S.S. Singh, S. Hasmi and D. Meena. 2021. Influence of plant growth regulators on growth, yield and quality of onion (*Allium cepa* L.). Pharma Innov. J. 10(9):725-727.
Tekeste, N., N. Dechassa, K. Woldetsadik, L. Dessalegne and A. Takele. 2018. Influence of nitrogen and phosphorus application on bulb yield and yield components of onion (*Allium cepa* L.). The Open Agric. J. 12: 194-206.
Thomas, G.W. 1982. Exchangeable cations. p. 159-165. In: A.L. Page, R.H. Miller and D.R. Keeney (eds.). Methods of Soil Analysis, Part II, Chemical and Microbiological Properties, 2nd Ed. Agronomy Monograph, Madison, WI, USA.
Zhao, X.-X., F.-J. Lin, H. Li, H.-B. Li, D.-T. Wu, F. Geng, et al. 2021. Recent advances in bioactive compounds, health functions, and safety concerns of onion (*Allium cepa* L.). Front. Nutr. 8. 8:669805.
Ziaf, K., M.W. Haider, A.U. Malik, R. Anwar and R. Riaz. 2019. Optimizing planting method and fertilizer application rate for producing high quality nursery of onion cv. Phulkara. Proceedings.36: 84.