Utilizing Capitulum Coverings Along with Application of Nitrogen and Phosphorus Enhances the Seed Yield of Sunflower

Amir Rahman[1], Habib Akbar[1], Hamza Ali[2*], Said Badshah[3], Sheraz Ahmed[3], Shahana Jabin[4], and Ghazal Muzaffar[5]

[1]Department of Agronomy, Faculty of Crop Production Sciences, The University of Agriculture, Peshawar-Pakistan

[2]Department of Horticulture, The University of Agriculture, Peshawar

[3]Agriculture Extension Department, Government of Khyber Pakhtunkhwa, Pakistan

[4]Department of Horticulture, PMAS Arid Agriculture University, Rawalpindi

[5]Department of Agriculture, University of Haripur, Pakistan

***Corresponding:** Hamzaali@aup.edu.pk

Citation | Rehman. A, Akbar. H, Ali. H, Badshah. S, Ahmed. S, Jabin. S, Muzaffar. G, "Utilizing Capitulum Coverings Along with Application of Nitrogen and Phosphorus Enhances the Seed Yield of Sunflower", IJASD, Vol. 07 Issue. 01 pp 54-64, March 2025.

Received | Feb 17, 2025 **Revised |** March 02, 2025 **Accepted |** March 04, 2025 **Published |** March 07, 2025.

Sunflower is an important oil crop whose production needs to be boosted by optimum nutrition. Understanding the responsive connection between nutrients and sunflower output is critical for its prudent management and maintaining higher yields. In this regard, an experiment using a randomized complete block design (RCBD) with split-plot arrangements and three replications was conducted at the Agriculture Research Station in Harichand, Charsadda, in 2022. Treatments included various levels of nitrogen and phosphorus, along with different capitulum coverings: muslin cloth, paper envelopes, and uncovered heads. Nitrogen and phosphorus treatments were assigned to main plots, while capitulum coverings were assigned to subplots. Results showed that the nitrogen at the rate of 150 kg ha^{-1} and phosphorous at the rate of 90 kg ha^{-1} significantly increased capitulum diameter, disk weight, seeds per capitulum, thousand-seed weight, final plant population at harvest, and seed yield compared to lower nitrogen and phosphorous rates. Nitrogen and phosphorus levels were not significantly associated with seed loss per capitulum. Muslin cloth covering of the capitulum significantly improved yield components, including seeds per capitulum, reduced seed loss per capitulum, seed yield, and harvest index, compared to paper envelope and uncovered treatments. The interaction of nitrogen and phosphorus levels significantly enhanced capitulum diameter, disk weight, seed yield, and harvest index. Based on these results, it is recommended to apply nitrogen at 150 kg ha^{-1} and phosphorus at 90 kg ha^{-1}, with capitulum coverings using muslin cloth, to maximize yield and yield components of sunflower.

Keywords: Sunflower, Nitrogen, Phosphorous, Capitulum Covering

Introduction:

The sunflower (*Helianthus annuus* L.) belongs to the family Compositae. The genus Helianthus includes approximately 65 species, of which 14 are annuals [1]. Native to eastern North America, sunflower ranks as the third most important oilseed crop in the Middle East, following soybean and palm oil, and is widely utilized for both oilseed and non-oilseed products, including bird feed and human snacks [2]. Globally, sunflower is the fourth-largest oilseed crop, with its seeds and dried stalks employed in food production and as fuel. Historically, sunflowers were used in ancient ceremonies and as ornamental plants [3].

In Pakistan, sunflower cultivation spans approximately 151,000 acres, producing 87,000 tons of seeds and 33,000 tons of oil annually. This crop is a major oilseed source for the country, primarily utilized for cooking oil production. Additionally, sunflowers provide raw materials for animal feed, non-edible industrial oil, and sunflower cake, which is a valuable livestock feed. They are also used in manufacturing margarine, soap, paint, varnish, and other products.

In typical farmer fields, sunflower yields average 1,520 kg per hectare, while advanced cultivation practices achieve yields of 3,800 kg per hectare. Under optimal conditions at research stations, yields can exceed 3,500 kg per hectare [4]. Despite these advancements, Pakistan faces a severe shortage of edible oil, aggravated by rapid population growth and rising living standards. A lack of high-yielding varieties and lower productivity per unit area further constrains production. Domestic oil output meets only 30% of the national demand, with the remaining 70% supplied through costly imports [5].

The commercial sunflower yield in Pakistan has fallen short of projections, primarily due to suboptimal agricultural practices, particularly in soil management, and significant losses from bird predation during critical stages such as sowing, germination, and flowering. Sunflower oil, a product of sunflower seeds, is widely recognized as a healthier cooking oil option due to its low saturated fat content, reducing the presence of harmful fats. As a vital oilseed crop globally, sunflower provides high-quality oil and dietary fiber that supports human health [6].

Sunflower is popular in Pakistan as an oilseed crop due to its short growing season and adaptability across diverse climates and soil types [7]. It ranks among the world's top four annual crops for edible oil production. Although introduced in Pakistan over 40 years ago, sunflower acreage and yield have shown variability due to multiple production and socio-economic constraints. Seed oil content ranges from 35% to 55%. Research highlights the crop's potential for growth across various soil types and climates in both rainfed and irrigated systems, suited to a range of agroecological zones.

The growth stages of a sunflower are crucial in understanding its development and optimizing agricultural practices. Sunflower growth can be divided into several distinct phases, beginning with germination, where the seed absorbs water and begins to sprout. The seedling stage follows, marked by the emergence of the first true leaves. As the plant progresses, it enters the vegetative phase, characterized by rapid leaf growth and stem elongation. During the reproductive phase, the sunflower forms its iconic large flower head, and pollination occurs. Finally, the plant reaches the maturity stage, where the flower heads dry, seeds are developed, and the plant prepares for harvest. Understanding these stages is essential for improving sunflower cultivation, including managing water, nutrients, and pest control during each phase [8].

Nitrogen (N) plays a critical role in plant biochemical processes, such as protein synthesis and biomass accumulation [9]. Adequate nitrogen levels in the soil during the vegetative and reproductive stages ensure high-quality grain production. Phosphorus (P) is similarly essential for plant metabolic processes. However, large amounts of phosphorus in soils can be unavailable to plants due to factors like the application method or soil pH [10]. Phosphorus contributes to flower development, seed production, and crop maturity [11]. When applied in precise amounts, phosphorus has been shown to enhance both grain weight and number [12]. Additionally, sulfur (S) is essential for increasing seed oil content and improving nitrogen and phosphorus use efficiency [13].

The primary nutrients required for plant growth and agricultural productivity are nitrogen, phosphorus, and potassium. Imbalances in any of these nutrients can result in abnormal growth patterns, making plants susceptible to disease and pest attacks [14] Given the significance of these nutrients, balanced fertilizer application is one approach to improve nutrient use efficiency (NUE). Nitrogen is particularly crucial for oilseed crops, as it influences their growth, protein levels, and overall yield. Applying nitrogen fertilizer enhances dry matter production and affects nitrogen accumulation and partitioning within plant tissues, which is essential for growth and development [15].

To protect sunflower heads from birds and squirrels, various methods can be employed. Covering mature sunflower heads with cheesecloth, poly-spun garden fleece, or paper bags can help preserve seeds while allowing light and airflow. According to Burpee, materials such as cheesecloth, fine pliable screens, and poly-spun garden fleece are ideal. Polyspun garden fleece, typically used to protect plants from frost, is effective due to its loosely woven structure, which deters squirrels while allowing airflow. In urgent situations, a paper bag with 3- to 5-inch holes cut in the top and sides can also suffice.

Granivorous bird flocks inflict significant damage to sunflower crops in major sunflower-growing regions worldwide, including Australia, China, Europe, India, and North America, as well as Pakistan, Russia, South America, and Ukraine. While comprehensive surveys on bird damage are sparse outside the United States, localized damage rates of up to 25% are frequently reported [16].

Objectives:

Effective nutrient management is crucial for increasing sunflower yields. Understanding the interactions between nutrient availability and sunflower productivity is vital, especially for resource-constrained farmers who rely on efficient nutrient use for sustainable crop management in the region. This study aimed to identify the best capitulum covering for the sunflower head to minimize the seed loss per capitulum and to find out the optimum doses of nitrogen and phosphorous for the optimum yield of sunflower.

Materials and Methods:

A field experiment entitled "Effect of nitrogen, phosphorus, and capitulum covering on the seed yield of sunflower" was conducted at Agriculture Research Station Harichand, Charsadda during the summer of 2022. The experiment was laid out in a Randomized Complete Block Design with split plot arrangements having three replications. The treatments were comprised of different levels of nitrogen × phosphorus and covering of the capitulum by Muslin cloth, paper envelope, and uncovered head. Two factors viz nitrogen and phosphorus were allotted to main plots while covering was allotted to subplots. The plot size was 2.5m x 3.5m (8.75 m^2) accommodating 5 rows used. The crop was sown on ridges with row-to-row distance of 70cm and plant-to-plant distance maintained at 25cm. The field was plowed through a cultivator to break the clods and remove the stubbles in the field followed by a rotavator to make a fine smooth seed bed. Weeds were removed manually through the sickle. The soil texture of the field was Sandy loam with low organic matter content and had a pH of 8 - 8.5. Single super phosphate (SSP) was used as a source of phosphorus and all of its doses were applied at sowing time, while urea was applied as nitrogen at a vegetative stage in a single dose. All the other conditions were kept constant during the experiment.

Factor A was Nitrogen levels (0, 90, 120, and 150 kg ha^{-1}) and Phosphorus levels (0, 60, and 90 kg ha^{-1}) while factor B was Disc covering materials (Uncovered head, Muslin cloth, and paper envelope).

Data was collected on the number of seeds $capitulum^{-1}$ which was calculated by randomly selecting five heads from every experiment unit and counting the seeds in it. Seed loss $capitulum^{-1}$ was noted by choosing 5 disk seeds in every experimental plot and counting the number of seeds lost then its average was taken. Thousands of seeds weight was calculated from each plot by randomly selecting 3 samples of thousand seeds from each plot and weighted on digital balance and then its mean was taken. Capitulum diameter (cm) was recorded by selecting five heads in every experimental unit, stately with the assistance of a meter tape in the middle of every head and then its mean was taken. Disc weight (g) was recorded by choosing five capitulums in every experimental unit and then was weighted through electrical balance and mean data was recorded. Plants at harvest ha^{-1} were recorded by counting the plant randomly in each row at harvesting time and taking its mean. Seed yield (kg ha^{-1}) was recorded by collecting seeds of the three central rows harvested and then weighted to record the seed yield. Recorded data was converted to kg ha^{-1} by the following formula:

$$\text{Seed yield (kg ha}^{-1}\text{)} = \frac{\text{Seed yield of the four central rows}}{\text{R} - \text{R distance} \times \text{R length} \times \text{No. of rows}} \times 10000\ \text{m}^2$$

Harvest index (%) was determined by using the following equation:

$$\text{Harvest index (\%)} = \frac{\text{Economical yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

Statistical Analysis:

The data collected during the experiment was statistically analyzed using the analysis of variance procedure for Randomized Complete Block Design. When the F value is significant, the means of the data were compared using LSD at a 5% level of probability [17].

Results:

Results from the study revealed that nitrogen significantly affected the capitulum diameter, seeds per capitulum, thousand seed weight, disk weight, seed yield, and harvest index of the sunflower. Phosphorus applications significantly improved the capitulum diameter (cm), disk weight (g), and thousand seed weight, plant at harvest/ha, seed yield (kg/ha), and seeds/capitulum of the sunflower. Different disk coverings also had a significant impact on seeds/capitulum, seed loss/capitulum, seed yield (kg/ha), and harvest index (%).

Mean data shows that nitrogen (N), phosphorus (P), and interaction between N × P significantly affected capitulum diameter, and disk weight while disk covering (DC) and all other interactions were not significant. Capitulum diameter (21cm) was higher in the plots treated with 150 kg N ha^{-1}, which was followed by 120 kg N ha^{-1} (20.3cm), while the lowest capitulum diameter (17.7cm) was recorded in the control plots (Figure. 1).

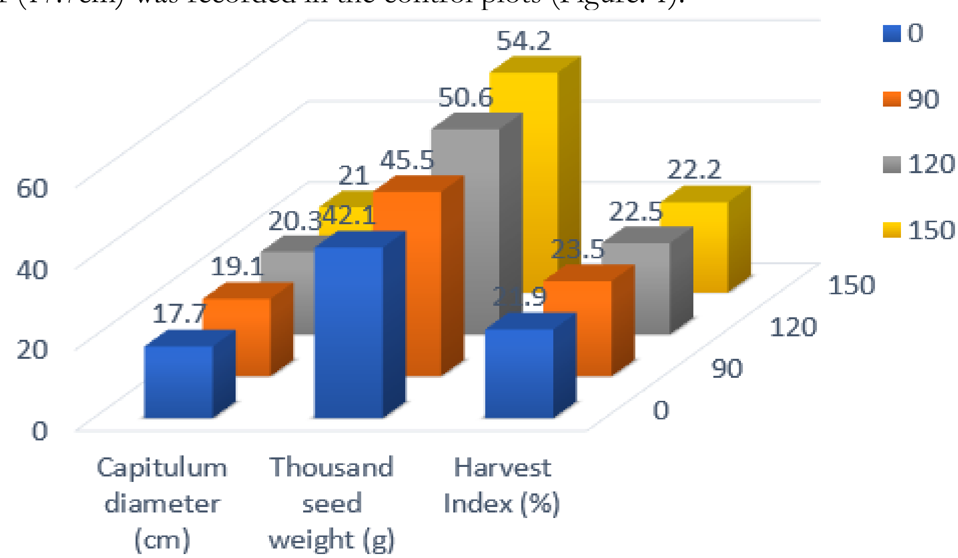

Figure 1: Influence of Nitrogen concentrations on the capitulum diameter (cm), thousand seed weight (g), and Harvest Index (%) of sunflower.

Similarly, the capitulum diameter (20cm) was higher in the plots where P was applied at the rate of 90 kg ha^{-1}, which was followed by 60 kg P ha^{-1} (19.6cm), while lowest capitulum diameter (18.9cm) was recorded in the control plots (Figure. 3). The interaction between nitrogen and phosphorus showed that plots received 150 kg N ha^{-1} and 90 kg P ha^{-1} have resulted in highest capitulum diameter (21.7cm), while lowest capitulum diameter (17.2cm) was recorded in the control plots.

Statistically similar and highest disk weight (402 and 406g) was recorded in the plots treated with 150 and 120 kg N ha^{-1}, followed by 90 kg N ha^{-1} (395g), while the lowest disk weight

(374g) was recorded in the control plot (Figure. 2). Maximum disk weight (426g) was recorded in plots where 90 kg P ha^{-1} was applied, while disk weight (343g) was greatly reduced in the control plots (Figure. 3). The interaction between nitrogen and phosphorus showed that plots received 150 kg N ha^{-1} and 90 kg P ha^{-1} have resulted highest disk weight (445g), while lowest disk weight (332g) was recorded in the control plots.

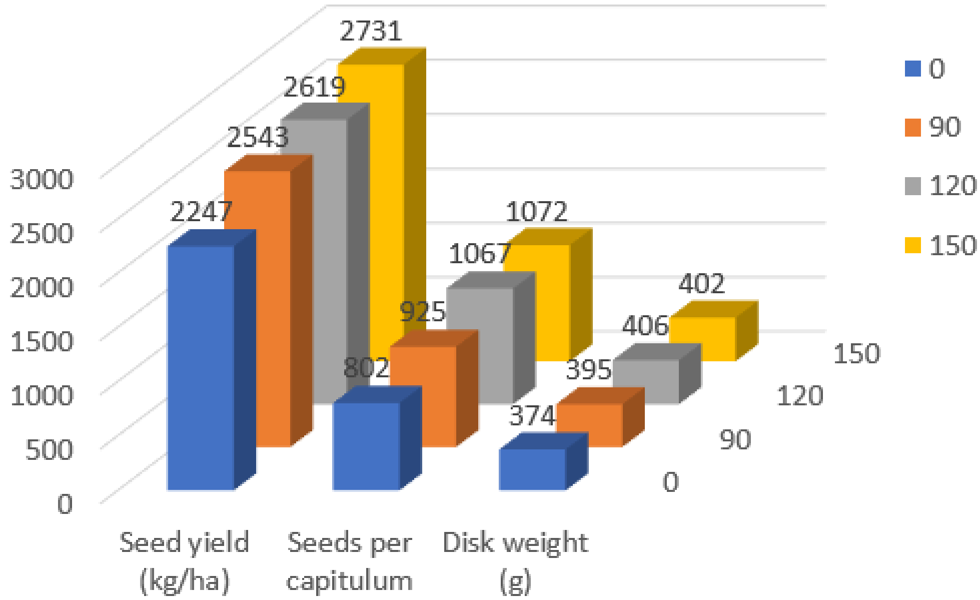

Figure 2: Influence of Nitrogen concentrations on the Seed yield (kg/ha), Seeds per capitulum, and disk weight (g) of sunflower.

A higher thousand seed weight (54.2g) was recorded in the plots treated with 150 kg N ha^{-1}, followed by 120 kg N ha^{-1} (50.6g), while a minimum thousand seed weight (42.1g) was recorded in the control plot (Figure. 1). Likewise, maximum thousand seeds weight (52g) was recorded in plots where 90 kg P ha^{-1} was applied, followed by 60 kg P ha^{-1} (47.9g), while minimum thousand seeds weight (44.4g) was noted in the control plots (Figure. 3).

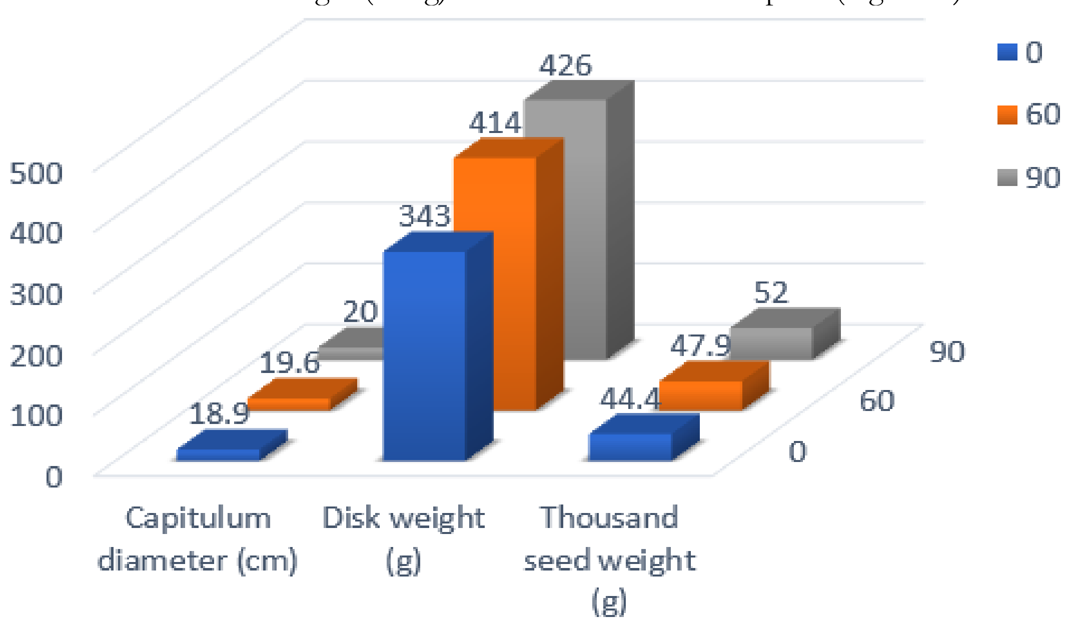

Figure 3: Influence of Phosphorus concentrations on the capitulum diameter (cm), disk weight (g), and thousand seed weight (g) of sunflower.

Nitrogen (N), phosphorus (P), and disk covering (DC) significantly affected number of seeds capitulum^{-1} and thousand seed weight while all interactions were not significant.

Statistically similar and higher number of seeds capitulum^{-1} (1072 and 1067) was recorded in the plots treated with 150 and 120 kg N ha^{-1}, respectively, followed by 90 kg N ha^{-1} (925), while minimum number of seeds capitulum^{-1} (802) was recorded in the control plot (Fig. 2). Maximum number of seeds capitulum^{-1}(1009) observed in plots where 90 kg P ha^{-1} was applied, while minimum number of seeds capitulum^{-1}(921) was observed in the control plots (Fig. 4). Application of disk covering showed that heads covered with muslin cloth resulted higher number of seeds capitulum^{-1} (981) as compared to paper envelope (965) and uncovered heads (953) (Figure. 5).

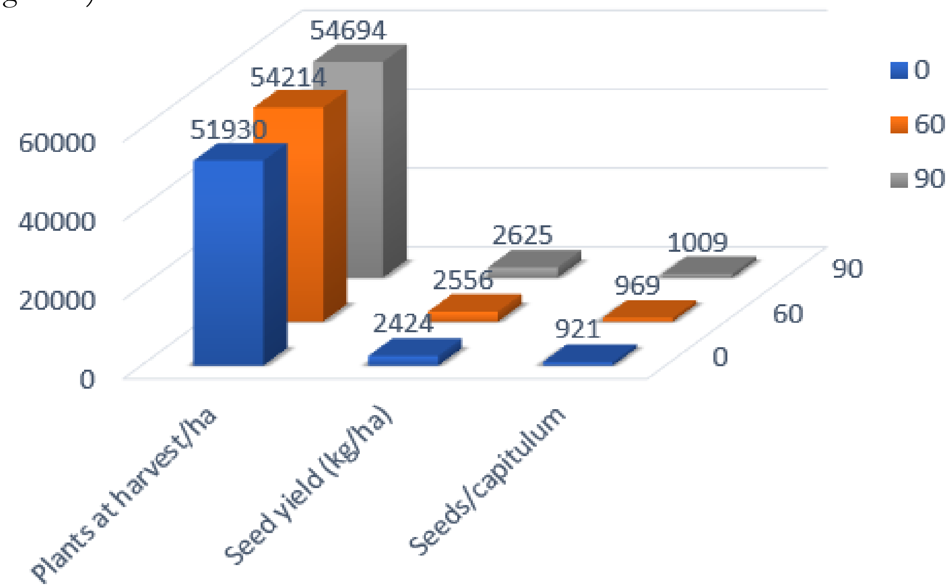

Figure 4: Influence of Phosphorus concentrations on the plant at harvest/ha, seed yield (kg/ha), and seeds/capitulum of sunflower.

Data regarding some seed loss capitulum^{-1} showed that nitrogen (N), and phosphorus (P) were found non-significant for seed loss capitulum^{-1} while disk covering (DC) significantly affected seed loss capitulum^{-1}, while all interactions were not significant. Application of disk covering showed that uncovered heads have resulted in maximum seed loss capitulum^{-1} (48) as compared to the paper envelope (46) and muslin cloth covering (44) (Figure. 5).

Nitrogen (N) and phosphorus (P) significantly affected the number of plants at harvesting, while the effect of disk covering (DC) and all interactions were not significant. The number of plants at harvesting (54438, 53687, and 53563) was statistically similar and higher in the plots treated with 150, 120, and 90 kg N ha^{-1}, respectively, while the lowest number of plants at harvesting (52762) was recorded in the control plot. Similarly, the highest number of plants at harvesting (54694 and 54214) was recorded in the plots treated with 90 and 60 kg P ha^{-1}, respectively, while the lowest number of plants at harvesting (51930) was recorded in the control plot (Figure. 4).

The mean data showed that among the different nitrogen levels, the application of 150 kg N ha^{-1} resulted in the highest seed yield (2731 kg ha^{-1}), which was followed by 120 kg N ha^{-1} (2619 kg ha^{-1}), while the lowest seed yield (2247 kg ha^{-1}) was recorded in the control plots (Fig 2). Similarly, the application of 90 kg P ha^{-1} produced the maximum seed yield (2625 kg ha^{-1}), which was followed by 60 kg P ha^{-1} (2556 kg ha^{-1}), while the lowest seed yield (2424 kg ha^{-1}) was recorded in the control plots. The interaction between nitrogen and phosphorus showed that plots received 150 kg N ha^{-1} and 90 kg P ha^{-1} resulted in the highest grain yield (2823 kg ha^{-1}), while the lowest grain yield (2135 kg ha^{-1}) was recorded in the control plots (Figure. 4).

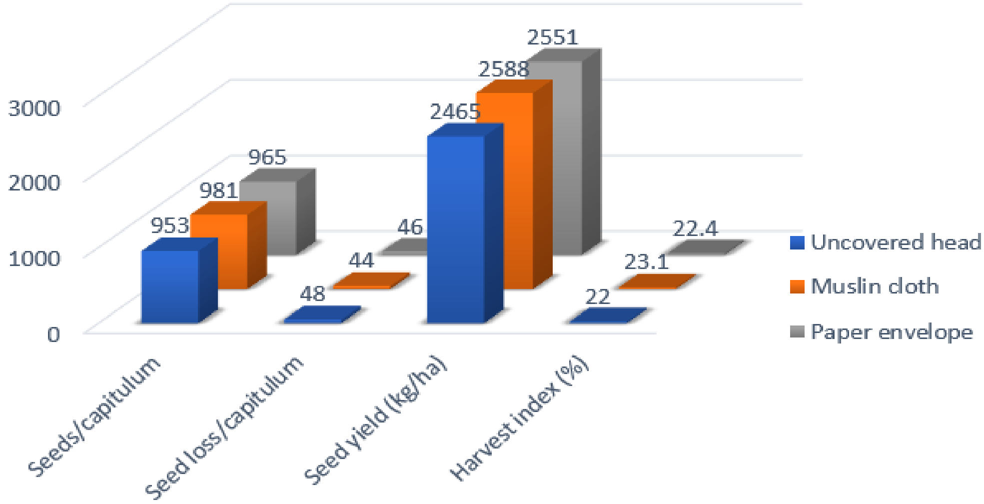

Figure 5: Influence of disk coverings on the seeds/capitulum, seed loss/capitulum, seed yield (kg/ha), and harvest index (%) of sunflower

Nitrogen (N), disk covering (DC), and N × P significantly affected the harvest index of sunflower, while the effect of phosphorus and all other interactions were not significant. Nitrogen at a rate of 90 kg ha^{-1}has resulted in highest harvest index (23.5%), as compared to 150 and 120 kg N ha^{-1} (22.2 and 22.5%), respectively, while lowest harvest index (21.9%) was recorded in the control plot (Fig. 1). Likewise, heads covered with muslin cloth has resulted in higher harvest index (23.1%) as compared to paper envelope and uncovered heads (22.4 and 22%) (Fig. 5). Mean data regarding N × P showed plots received 150 kg N ha^{-1} and 90 kg P ha^{-1} have resulted in highest harvest index (22.5%), while lowest harvest index (22.1%) was recorded in the control plots.

Discussions:

Sunflower is an important oil seed plant whose physiological processes are greatly influenced by the application of nitrogen. It nourishes the plant and enhances the vegetative growth promoting the leaf area that leads to higher photosynthetic activity that improves energy availability and promotes the growth of the capitulum [18]. It leads to a higher capitulum diameter having more seeds per capitulum and contributes to the seed yield of sunflower. It favors the accumulation of more carbohydrates which when supplied to developing seeds in the capitulum promotes seed formation as it is crucial for the reproductive organ development during the blooming stage. Nitrogen promotes cell division and elongation that leads to higher weight of seeds thus improving the thousand seed weight. Higher seed weight ultimately leads to larger and heavier disks. Moreover, nitrogen improves protein production and other cellular entities that enhance the weight of the disk [19].

It also improves the reproductive and vegetative attributes of the plant leading to enhanced seed formation. Optimum nitrogen supply enables the plant to provide more nourishment to the flower heads of the sunflower plant and leads to enhanced seed yield. Harvest index ratio is the ratio of seed yield to the total biomass of the plant. Nitrogen enhances the plant biomass as more food is available to increase the yield of the plant. It improves the resource allocation to reproductive organs and its excess as well as deficiency can lead to reduced yield [20].

Phosphorous plays a key role in the development and growth of sunflowers. It directly influences the metabolism, development of roots, and reproductive processes that directly affect the yield. It develops a strong root system that enhances the nutrient uptake by the plants and facilitates nutrient distribution throughout the plants, particularly in the reproductive stages when the flower head formation starts [21]. It's the main component of energy molecules ATP that runs all the activities in the plants. A sufficient supply of phosphorous contributes to the improved capitulum diameter of the sunflower because more energy is being distributed to the cell elongation and division [22].

Phosphorous influences the carbohydrates storage within the seed and promotes the nucleic acid and protein formation for seed development which leads to larger and heavier seeds thus enhancing the thousand seed weight. Similarly, the disk weight of the sunflower is enhanced by the phosphorous application as it ensures that optimum resources are available for the production of tissues and nutrients are allocated to seeds. It plays a role in building the structural components of the plants and promoting the disk weight. The number of seeds per capitulum is also improved by an optimum supply of phosphorous [23]. It promotes pollen viability and seed setting leading to more seeds formed in the disk. It also regulates the physiological processes that are responsible for the maturation of the seed, higher seed quality, and better nutrient storage capability. Its ability to improve photosynthesis and cell division leads to better seed formation that ultimately results in enhanced seed yield of sunflowers [24].

Phosphorous enhances the root system of the plant and enhances the ability of the plants to absorb optimum nutrients and water which in turn promotes the growth and development of the plant. A strong root system increases the chances of plant survival and improves the density of plants per hectare [25]. The nitrogen and phosphorous enhance the overall performance of the sunflower crop but its seeds are lost due to various reasons among which seed loss due to bird attacks is a common issue. Different capitulum coverings were used to address this issue. Among these muslin cloth is an economical, lightweight, and breathable option that promotes air circulation in the capitulum. It supports optimal seed development by improving the moisture conditions of the capitulum reducing the chances of diseases and ensuring the production of quality seeds. It also protects the capitulum from adverse environmental conditions as well as pests [26].

More seeds are available per capitulum as muslin cloth prevents the capitulum from being damaged and provides a microenvironment for the seed formation leading to higher seed set in contrast to no covering and paper envelope which hinders the flow of air. Muslin cloth protects the capitulum and reduces the seed loss per capitulum. No covering is unsecured and the capitulum is damaged during harsh weather conditions which leads to significant seed loss. Paper coverings offer some level of protection but it restricts the air flow and lead to higher moisture content. This higher moisture level leads to fungal diseases and mold growth that ultimately leads to the rotting of seeds and seed drops [27].

The seed yield of the sunflower is enhanced as the nitrogen and phosphorous contribute to the enhanced seed production and muslin covering protects the seeds from falling off and reduces the losses up to a great extent and ultimately contributes to the improved harvest index. Muslin cloth better improves the attributes as compared to paper covering due to its lightweight fabric that promotes airflow and reduces the incidence of fungal infections. It provides better protection from adverse conditions and mechanical and physical damage. Muslin cloth maintains a stable microclimate that guards the seeds from high temperatures and protects them from negative impacts. The breathable nature of muslin cloth combined with its efficiency in protecting it from all sorts of stressors makes it more effective and leads to a healthy crop with more seeds/capitulum, seed yield, harvest index, and least seed loss.

Conclusions:

The highest rate of nitrogen (150 kg ha^{-1}) enhanced the vegetative parameters i.e., capitulum diameter, disk weight, plants m^{-2}, and improved yield parameters i.e., thousand seed weight, seeds $capitulum^{-1}$, and seed yield as compared to lower rates. The highest rate of phosphorus (90 kg ha^{-1}) enhanced plant growth, yield, and yield components as compared to 60 and 0 kg P ha^{-1}. The head covered with muslin cloth and the paper envelope significantly improved the number of seed $capitulum^{-1}$, seed yield, and harvest index and resulted in minimum seed loss $capitulum^{-1}$, as compared to the uncovered head. The interactive effect of N × P has significantly enhanced capitulum diameter (cm), disk weight (g), biological yield, seed yield, and harvest index. In the light of the current study, nitrogen at a rate of 150 kg ha^{-1} and phosphorus at a rate of 90 kg ha^{-1} along with the application of head covering material i.e., muslin cloth is recommended for enhanced yield of sunflower.

Conflict of Interest:

All the authors declare no conflict of interest.

Authors Contributions:

H.A. conceived the idea and supervised the experiment, A.R. performed the experiment, H.A. and S.J. prepared the manuscript, S.B. and S.A. provided technical assistance during the experiment, and G.M. proofread the manuscript.

References:

[1] R. L. Andrew, N. C. Kane, G. J. Baute, C. J. Grassa, and L. H. Rieseberg, "Recent nonhybrid origin of sunflower ecotypes in a novel habitat," *Mol. Ecol.*, vol. 22, no. 3, pp. 799–813, Feb. 2013, doi: 10.1111/MEC.12038.

[2] M. Charney, "Sunflower seeds and their products," *J. Agric. Food Inf.*, vol. 11, no. 2, pp. 81–89, Apr. 2010, doi: 10.1080/10496501003689574/ASSET//CMS/ASSET/B6A94AC1-1EEE-4D23-BA88-369569105090/10496501003689574.FP.PNG.

[3] M. H. Muller, M. Latreille, and C. Tollon, "The origin and evolution of a recent agricultural weed: population genetic diversity of weedy populations of sunflower (Helianthus annuus L.) in Spain and France," *Evol. Appl.*, vol. 4, no. 3, pp. 499–514, May 2011, doi: 10.1111/J.1752-4571.2010.00163.X.

[4] "(PDF) Trends in sunflower production and its potential in increasing domestic edible oil production in Punjab, Pakistan." Accessed: Feb. 22, 2025. [Online]. Available: https://www.researchgate.net/publication/268801026_Trends_in_sunflower_production_and_its_potential_in_increasing_domestic_edible_oil_production_in_Punjab_Pakistan

[5] "Performance of vegetable soybean germplasm under Peshawar valley conditions | Request PDF." Accessed: Feb. 22, 2025. [Online]. Available: https://www.researchgate.net/publication/292742689_Performance_of_vegetable_soybean_germplasm_under_Peshawar_valley_conditions

[6] M. K. K. Sheeba Khan, Saumya Choudhary, Anamika Pandey, "Sunflower oil: Efficient oil source for human consumption," *Emerg. Life Sci. Res*, vol. 1, no. 1, pp. 1–3, 2015, [Online]. Available: https://www.researchgate.net/publication/308032797_Sunflower_oil_Efficient_oil_source_for_human_consumption

[7] F. K. Muhammad Nisar Khan, Arshad Mahmood Malik, "Performance and Instability of Oilseed Crops in Pakistan," *Proc. Pakistan Acad. Sci.*, vol. 61, no. 1, 2024, [Online]. Available: https://ppaspk.org/index.php/PPAS-B/article/view/1350

[8] E. J. Philippe Debaeke, Laurent Bedoussac, Catherine Bonnet, Emmanuelle Bret-Mestries, Célia Seassau, André Gavaland, Didier Raffaillac, Hélène Tribouillois, Grégory Véricel, "Sunflower crop: environmental-friendly and agroecological," *OCL*, vol. 24, no. 3, 2017, doi: https://doi.org/10.1051/ocl/2017020.

[9] A. . Leghari, S.J., N.A. Wahocho, G.M. Laghari, A. HafeezLaghari, G. MustafaBhabhan, K. HussainTalpur, T.A. Bhutto, S.A. Wahocho, A.A. Lashari, "Role of Nitrogen for Plant Growth and Development: A review," *Adv. Environ. Biol.*, vol. 10, no. 9, pp. 209–218, 2016, [Online]. Available: https://www.researchgate.net/publication/309704090_Role_of_Nitrogen_for_Plant_Growth_and_Development_A_review

[10] V. V. Shenoy and G. M. Kalagudi, "Enhancing plant phosphorus use efficiency for

sustainable cropping," *Biotechnol. Adv.*, vol. 23, no. 7–8, pp. 501–513, Nov. 2005, doi: 10.1016/J.BIOTECHADV.2005.01.004.
[11] M. A. Osman, E.B.A., "RESPONSE OF SUNFLOWER (HELIANTHUS ANNUUS L.) TO PHOSPHORUS AND NITROGEN FERTILIZATION UNDER DIFFERENT PLANT SPACING AT NEW VALLEY," *Ass. Univ. Bull. Environ. Res*, 2010, doi: 10.21608/auber.2010.149260.
[12] M. A. M. A. Khan, M.K., "Fertilizer N- and P-rates Response on sunflower intercropping with Mung bean in North-West, Pakistan," *Basic Res. J. Agric. Sci. Rev*, vol. 3, no. 12, pp. 146–160, 2014.
[13] "Influence of sulphur level on yield, uptake and quality of soybean (Glycine max) under temperate conditions of Kashmir valley | Request PDF." Accessed: Feb. 22, 2025. [Online]. Available: https://www.researchgate.net/publication/274512755_Influence_of_sulphur_level_on_yield_uptake_and_quality_of_soybean_Glycine_max_under_temperate_conditions_of_Kashmir_valley
[14] "(PDF) Physiology, phenology and yield of sunflower (autumn) as affected by NPK fertilizer and hybrids." Accessed: Feb. 22, 2025. [Online]. Available: https://www.researchgate.net/publication/266287896_Physiology_phenology_and_yield_of_sunflower_autumn_as_affected_by_NPK_fertilizer_and_hybrids
[15] P. Fan *et al.*, "Nitrogen availability determines the vertical patterns of accumulation, partitioning, and reallocation of dry matter and nitrogen in maize," *F. Crop. Res.*, vol. 297, p. 108927, Jun. 2023, doi: 10.1016/J.FCR.2023.108927.
[16] A. Khaleghizadeh, "Effect of morphological traits of plant, head and seed of sunflower hybrids on house sparrow damage rate," *Crop Prot.*, vol. 30, no. 3, pp. 360–367, Mar. 2011, doi: 10.1016/J.CROPRO.2010.12.023.
[17] Hamza Ali, Masood Ahmad, Shahana Jabin, Raja Zohaib Muqarrab, Imran Ahmad, Muskan Alam Khan, Mansoor Khan, Ibadullah Khalil, Abdul Basit, Mustafa Kamal, "Influence of willow bark extracts and application times on the production of Roselle," *Plant Prot.*, vol. 8, no. 4, 2024, [Online]. Available: https://esciencepress.net/journals/index.php/PP/article/view/5422
[18] "Review on the effect of organic fertilizers, biofertilizers and inorganic fertilizers (NPK) on growth and flower yield of marigold (Tagetes erecta L.) - Google Search." Accessed: Feb. 22, 2025. [Online]. Available: https://www.google.com/search?q=Review+on+the+effect+of+organic+fertilizers%2C+biofertilizers+and+inorganic+fertilizers+(NPK)+on+growth+and+flower+yield+of+marigold+(Tagetes+erecta+L.)&oq=Review+on+the+effect+of+organic+fertilizers%2C+biofertilizers+and+inorganic+fertilizers+(NPK)+on+growth+and+flower+yield+of+marigold+(Tagetes+erecta+L.)&gs_lcrp=EgZjaHJvbWUyBggAEEUYOdIBBzY1M2owajeoAgiwAgHxBSOWzUecjQoo&sourceid=chrome&ie=UTF-8
[19] N. L. Nurah M. Alzamel, Eman M. M. Taha, Eman M. M. Taha, "Effect of Organic and Inorganic Fertilizers on Soil Properties, Growth Yield, and Physiochemical Properties of Sunflower Seeds and Oils," *Sustainability*, vol. 14, no. 19, p. 12928, 2022, doi: https://doi.org/10.3390/su141912928.
[20] T. R. Sinclair and T. W. Rufty, "Nitrogen and water resources commonly limit crop yield increases, not necessarily plant genetics," *Glob. Food Sec.*, vol. 1, no. 2, pp. 94–98, Dec. 2012, doi: 10.1016/J.GFS.2012.07.001.
[21] H.-J. Kim and X. Li, "Effects of Phosphorus on Shoot and Root Growth, Partitioning, and Phosphorus Utilization Efficiency in Lantana," *HortScience*, vol. 51, no. 8, pp. 1001–1009, 2016, doi: https://doi.org/10.21273/HORTSCI.51.8.1001.
[22] M. . Kolanyane, "The influence of nitrogen and phosphorus nutrition on growth and

yield components of safflower (Carthamus tinctorius)," *Dr. Diss. Botswana Univ. Agric. Nat. Resour.*, 2022, [Online]. Available: http://researchhub.buan.ac.bw/handle/13049/534
[23] B. M. Bera, A.K., K. Pramanik, "Response of biofertilizers and homo-brassinolide on growth, yield and oil content of sunflower (Helianthus annuus L.)," *African J. Agric. Res.*, vol. 9, no. 48, pp. 3494–3503, 2014, doi: https://doi.org/10.5897/AJAR2013.8457.
[24] M. Hussain *et al.*, "Drought stress in sunflower: Physiological effects and its management through breeding and agronomic alternatives," *Agric. Water Manag.*, vol. 201, pp. 152–166, Mar. 2018, doi: 10.1016/J.AGWAT.2018.01.028.
[25] C. T. Iko T. KoevoetsIko T. Koevoets, Jan Henk VenemaJan Henk Venema, J. Theo. M. ElzengaJ. Theo. M. Elzenga, Christa Testerink, "Roots Withstanding their Environment: Exploiting Root System Architecture Responses to Abiotic Stress to Improve Crop Tolerance," *Frontiers (Boulder).*, vol. 7, 2016, doi: https://doi.org/10.3389/fpls.2016.01335.
[26] S. Rauf, "Breeding Strategies for Sunflower (Helianthus annuus L.) Genetic Improvement," *Adv. Plant Breed. Strateg. Ind. Food Crop.*, vol. 6, pp. 637–673, Oct. 2019, doi: 10.1007/978-3-030-23265-8_16.
[27] D. Mohapatra, S. Kumar, N. Kotwaliwale, and K. K. Singh, "Critical factors responsible for fungi growth in stored food grains and non-Chemical approaches for their control," *Ind. Crops Prod.*, vol. 108, pp. 162–182, Dec. 2017, doi: 10.1016/J.INDCROP.2017.06.039.