Research Article

Pre and Post Anthesis Dry Matter Partitioning in Sunflower Influenced by Green Manuring and Nutrient Management

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Abstract | Partitioning of dry matter is an essential process for obtaining optimum yield in sunflower. Allocation of assimilates to different parts of plant at various growth stages not only enhance crop growth but also contribute in the final yield and quality of sunflower. This research investigates the influence of green manuring and nutrients management on pre and post-anthesis dry matter partitioning and its relation with yield. With this aim a two-year research study was conducted with two levels of green manuring, i.e., no green manuring and green manuring with berseem, nitrogen (0, 60, 90 and 120 kg ha^{-1}) and sulfur (0, 15, 30 and 45 kg ha^{-1}) levels. The findings revealed that total dry matter partitioning at both stages was significantly affected by green manuring, nitrogen and sulfur levels. Dry matter partitioning to stem, leaves and heads at both pre- and post-anthesis stages were higher in the plots incorporated with berseem crop as green manuring as compared to no green manuring. Higher values of dry matter partitioned to leaves, stem and heads at both stages were higher with addition of 120 kg N ha^{-1}. Among different sulphur levels dry matter partitioned to various plant parts were higher with addition of 45 kg S ha^{-1}. Similarly total yield was also significantly affected by green manuring and varying levels of nitrogen and sulphur. Green manured plots produced higher yield as compared to no green manuring. Nitrogen application at the rate of 120 kg ha^{-1} produced higher yield. Application of 45 kg S ha^{-1} produced maximum yield of sunflower. These findings suggested that addition of nitrogen at the rate of 120 kg ha^{-1} along with green manuring and sulphur application at the rate of 45 kg ha^{-1} improved crop growth and dry matter production and contributed to higher yield.

Received | June 18, 2025; **Accepted** | Oct 1, 2025; **Published** | December 26, 2025
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Citation | Khan, B., A.A. Khan, Amanullah and D. Muhammad. 2025. Pre and post anthesis dry matter partitioning in sunflower influenced by green manuring and nutrient management. *Sarhad Journal of Agriculture,* 41(5): 238-247.
DOI | https://dx.doi.org/10.17582/journal.sja/2025/41.5.238.247
Keywords | Sunflower, Yield, Dry matter partitioning, Nitrogen, Sulphur, Green manuring.

Introduction

The sunflower is an important and widely grown oilseed crop having various nutritional benefits. It occupied most of the cultivated land and have higher production than any other oilseed crop (Adeleke and Babalola, 2020). Specific portion of cultivable land reserved for cultivation of sunflower and which contribute about 9% of the total arable land. Approximately, 25 million hectares of land is being cultivated with sunflower crop with a production of 48 million tonnes (Debaeke *et al*., 2023). It has exceptional benefits in terms of nutrition as its oil contains higher amount of linoleic acid which has various beneficial effects on health (Asif *et al*., 2023). Edible oil is the key commodity in agriculture economy after food crops. In Pakistan, large quantity of required edible oil is imported because domestic production of edible oil is very low (MNFSR, 2023). It was grown on 141254 hectares and total production was 168625 tons in Pakistan. In Khyber Pakhtunkhwa, it was grown on 242 hectares with a total production of about 387 tons (Sher *et al*., 2022). Sunflower crop has the potential to reduce the import bill of edible oil by enhancing domestic oil production. As sunflower is photo-insensitive and short duration crop as well as have higher adoptability to various agro-climatic conditions. However, besides the potentiality of the sunflower still its production is very low in the country (Javaid *et al*., 2024).

Numerous factors are responsible for obtaining potential production of crop. Fertilizer management is an important factor among them which can boost crop growth and production by supplying sufficient amount of nutrients required (Adeleke and Babalola, 2020). Nutrients availability is a key factors that govern sunflower yield (Ren *et al*., 2025). Addition of fertilizer boosts crop yield by enhancing soil fertility and nutrients uptake by plants (Kalaiyarasan *et al*., 2020). Nitrogen is one of the important nutrient that determine sunflower yield in intensive agriculture (Javaid *et al*., 2024). Nitrogen plays a key part in crop growth and development as it is the constituent of different types of proteins, nucleic acids and chlorophyll, still it is the most deficient nutrient in our soils (Mahboob *et al*., 2023). Nitrogen is one of the momentous supplements that boost the metabolic pathways that is prompts increments in vegetative, light of protein, conceptive development and production of the harvest as it has a vital role in improvement and development of product (Chen *et al*., 2025).

Sulphur is another nutrient required by the crop in large amount and its demand is higher in oilseed crop. It is ranked fourth after nitrogen, phosphorus and potassium in nutrients required for crop (Indu and Singh, 2020). It plays a predominant part in enhancing quality of grain and efficiency of other nutrients like N and P (Hussain *et al*., 2025). It also boosts crop yield and oil quality of oilseed crop (Rahangdale *et al*., 2024). Pakistan soils are mostly deficient in available sulfur and this is the reason for lower yield of sunflower crop (Javaid *et al*., 2024). Sulfur application to sunflower crop improves yield and yield related traits like capitulum size, seed weight, dry matter (Asif *et al*., 2023). To maximize crop yield, particularly for sunflower, effective fertilizer management is crucial as it ensures the availability of essential nutrients, being especially vital for boosting plant growth, development, and overall production.

Another factor for lower crop productivity is the availability of nutrients to plant. Most of the growers use huge amount of synthetic fertilizer and rarely apply organic manures, which causes soil degradation and health problems. Green manuring may contribute to soil nutrient dynamics and improve soil health (Fanish, 2018). It is nowadays an important practices which is environmental friendly and contribute towards soil fertility, retention of organic matter and overall improving soil health (Zhao *et al*., 2024). Green manuring significantly improves bioavailability of nutrients and soil nutrient dynamics (Acs *et al*., 2025) as well as reduces leaching of certain nutrients including nitrogen and improved soil carbon and physical properties (Nguyen *et al*., 2024). Legume crop cultivation reduced the required amount of nitrogen fertilizer and is an environmental friendly practice by lowering greenhouse gases emission (Kamran *et al*., 2025).

Although the documented benefits of these practices, a comprehensive study is still needed to find out the optimal levels and combinations of sulphur and nitrogen along with green manuring to improve sunflower growth and yield. This study was investigated with objectives to individual and combined effects of these factors on dry matter partitioning as well as yield of sunflower in the study area.

Materials and Methods

Experimental site and design

The research was carried out at research farms of the department of Agronomy, The University of Agriculture Peshawar, Pakistan, during spring 2019 and 2020. The experiment was established using randomized complete block design in factorial arrangements with three replications. The average temperature of the experimental site is from 24-32°C and average monthly rainfall is about 20mm during the spring season.

Treatment details

The research was consisted of three factors including nitrogen, sulphur and green manuring. Nitrogen was applied at three levels, i.e. 0, 60, 90 and 120 kg N ha^{-1}. Sulphur was applied at the rate of 0, 15, 30 and 45 kg S ha^{-1}. Green manuring was consisted of two levels, i.e., with green manuring and without green manuring. Berseem crop was used as green manure at the rate of 10 ton ha^{-1}. Nitrogen was applied from urea and sulphur in the form of 'Kumulus DF', a product of FMC company contains 80 % sulfur by weight.

Crop management

A fine seedbed was prepared by thoroughly ploughing the field with cultivator followed by rotavator. Sunflower hybrid 'HySun 33' was sown in February, 2019 and 2020 at the seed rate of 10 kg ha^{-1}. Nitrogen was applied in two splits ,i.e., half at seedbed preparation and half nitrogen was applied 30 days after sowing. Phosphorus and potassium fertilizers were applied at the time of seedbed preparation at the rate of 60 kg ha^{-1} from single super phosphate and muriate of potash, respectively. All sulphur fertilizer was applied at sowing time as single dose. Four irrigations were applied at 15 days interval (however, weather conditions and crop water requirement were kept in mind and irrigation interval was managed accordingly). All other agronomic practices (like hoeing, weeding, etc.) were kept constant for successful crop production. Weeding was practiced manually using hand hoe and at the same time manual hoeing was practiced.

Green manuring

Berseem crop was grown in winter season (last week of November) at seed rate of 8 kg ha^{-1} in standing water and was incorporated as green manure at the rate of 10 tons ha^{-1} (12.6 kg plot^{-1}) three weeks before sowing of sunflower. The green manure crop was mixed in soil with the help of rotavator.

Observations

Data was recorded on pre- and post-anthesis dry matter partitioning. Data were recorded on weighing dry samples obtained randomly form the plots side rows and the different plant parts were separately weighed at two stages, i.e., pre-anthesis stage and post-harvest (at maturity). For recording total yield data, four central rows were harvested and sun dried and weighed with digital balance. Data were then converted to standard units.

Statistical analysis

The data were analyzed following the randomized complete block (RCB) design. Treatment means were compared using the Least Significant Difference (LSD) test at a 5% level of probability if the F-test was significant (Jan *et al*., 2009).

Results

Dry matter (DM) partitioning at pre-anthesis stage

Total DM at pre-anthesis stage was significantly influenced by green manuring (G), nitrogen (N) and sulfur (S) levels (Table 1). The interaction GM×N was the only significant interaction and the rest of the interactions were insignificant. Green manuring with berseem crop produced higher dry matter (1002 g m^{-2}) as compared to no green manuring (895 g m^{-2}). Increasing nitrogen from 0 to 120 kg linearly increased pre-anthesis dry matter. Greater dry matter (1025 g m^{-2}) was produced with addition of 120 kg nitrogen per hectare. Lowest dry matter (874 g m^{-2}) was produced with no N application. Increasing sulfur dose from 0 to 45 kg ha^{-1} improved DM production. Using 45 kg sulfur ha^{-1} produced greater dry matter (1015 g m^{-2}). Minimum dry matter (880 g m^{-2}) was accumulated in control plots. The GM×N interaction depicted that increasing nitrogen levels increased dry matter production with or without green manuring, however the increase was more prominent with green manuring (Figure 1).

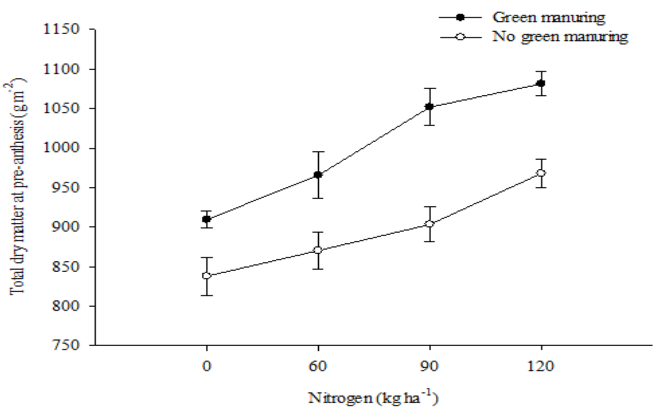

Figure 1: *Interactive effect of green manuring and nitrogen on total dry matter at pre-anthesis stage*

Dry matter partitioning to stem was considerably affected by green manuring and various levels of nitrogen and sulphur (Table 1). No interaction was found significant. Mean values revealed that green manuring with berseem crop have higher stem dry matter (421 g m^{-2}) as compared to no green manuring

(377 g m^{-2}). Stem dry matter was elevated with each increment in N dose. Stem DM was maximum (432 g m^{-2}) with addition of 120 kg N ha^{-1}. Allocation of dry matter to stem was lower (367 g m^{-2}) with no nitrogen application. Similarly increasing sulfur level increased stem dry matter at pre-anthesis stage consistently. Addition of 45 kg S ha^{-1} allocated more dry matter (426 g m^{-2}) to stem. No sulfur application produced minimum stem dry matter (369 g m^{-2}).

Table 1: *Dry matter production and partitioning to various plant parts (g m^{-2}) at pre-anthesis of sunflower as influenced by green manuring, nitrogen and sulfur.*

Green manuring (GM)	Dry matter production at Pre-anthesis (g m^{-2})			
	Total	Stem	Leaves	Head
No green manuring	895 b	377 b	326 b	190 b
Berseem green manuring	1002 a	421 a	365 a	216 a
Significance	**	**	**	**
Nitrogen (N) (kg ha^{-1})				
0	874 d	367 d	319 d	186 d
60	918 c	386 c	337 c	198 c
90	978 b	410 b	356 b	208 b
120	1025 a	432 a	371 a	220 a
$LSD_{(P=5\%)}$	28	12	11	8
Sulfur (S) (kg ha^{-1})				
0	880 d	369 d	323 d	189 c
15	925 c	392 c	336 c	202 b
30	974 b	409 b	354 b	205 b
45	1015 a	426 a	370 a	216 a
$LSD_{(P=5\%)}$	28	12	11	8
Interactions	**Significance**			
GM x N	*	NS	*	NS
GM x S	NS	NS	NS	NS
N x S	NS	NS	NS	NS
GM x N x S	NS	NS	NS	NS

Means of each category followed by same letters are statistically at par with each other at 5% level of probability . "" = significant at 5% level of probability, "**" = significant at 1% level of probability, "NS" = Non-significant*

Significant effect of green manuring, N and S doses on leaf dry matter production at pre-anthesis. The interaction GM×N was found significant and the rest were insignificant. Green manuring with berseem crop produced higher leaf DM (365 g m^{-2}) as compared to no green manuring (326 g m^{-2}). Among different nitrogen levels, increasing nitrogen from 0 to 120 kg linearly increased pre-anthesis leaf dry matter. Higher leaf dry matter (371 g m^{-2}) was produced with addition of 120 kg N ha^{-1}. Minimum leaf dry matter (319 g m^{-2}) was produced in control plots. Mean values regarding sulfur levels revealed that increasing sulfur application from 0 to 45 kg ha^{-1} increased leaf dry matter production. Application of 45 kg sulfur ha^{-1} produced higher leaf dry matter (370 g m^{-2}). Minimum leaf dry matter (323 g m^{-2}) was attained from plots received no sulfur. The interaction between GM×N indicated that increasing nitrogen levels increased leaf dry matter production with or without green manuring, however the increase was more prominent with green manuring (Figure 2).

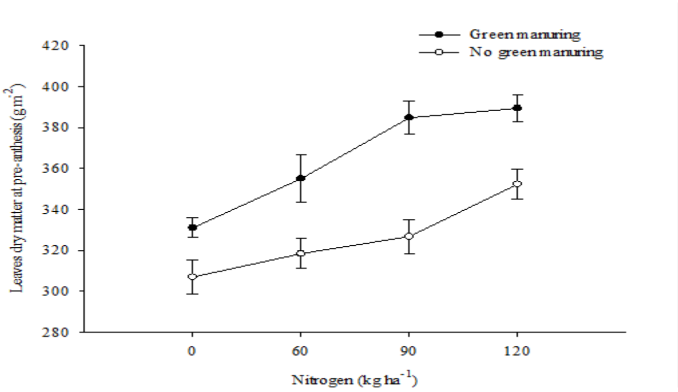

Figure 2: *Interactive effect of green manuring and nitrogen on leaf dry matter at pre-anthesis stage*

Head dry matter accumulation at pre-anthesis of sunflower was profoundly varied by green manuring, nitrogen and sulfur. The interactive effect of these factors were not significant. Green manuring with berseem crop have higher head dry matter (216 g m^{-2}) as compared to no green manuring (190 g m^{-2}). Dry matter in head was accumulated at elevated rate with rise in each dose of N. Head dry matter was greater (220 g m^{-2}) with application of 120 kg N ha^{-1}. Head dry matter was lower (186 g m^{-2}) with no nitrogen application. Similarly increasing sulfur level increased head dry matter at pre-anthesis stage consistently. Addition of 45 kg sulfur accumulated more dry matter (216 g m^{-2}) to head. No sulfur application produced minimum head dry matter (189 g m^{-2}).

Dry matter (DM) partitioning at post-harvest stage

Data on total dry matter at post-harvest stage with respect to various green manuring, nitrogen and sulfur levels are computed in Table 2. Statistical perusal of the data shown significant effect of green manuring, nitrogen and sulfur doses on total dry matter production at post-harvest. The interaction GM×N was profound while the rest were insignificant.

Green manuring increased dry matter production at post-harvest (1175 g m^{-2}) as compared to no green manuring (1033 g m^{-2}). Increasing nitrogen levels linearly increased dry matter production at post-harvest. Higher dry matter at post-harvest (1197 g m^{-2}) was recorded with 120 kg N ha^{-1}. Minimum dry matter at post-harvest (1005 g m^{-2}) was observed with no N application. Sulfur application increased dry matter production at post-harvest. Higher dry matter at post-anthesis (1196 g m^{-2}) was produced with addition of 45 kg S ha^{-1}, which was followed by (1141 g m^{-2}) 30 kg S ha^{-1}. Lower dry matter at post-anthesis (1012 g m^{-2}) was produced with no sulfur application. The interaction between GM×N shown that increasing nitrogen level increased dry matter production at post-anthesis regardless of green manuring, however the increased was more prominent with increasing nitrogen along with green manuring (Figure 3).

Table 2: *Dry matter production and partitioning to various plant parts (g m^{-2}) at post-harvest of sunflower as influenced by green manuring, nitrogen and sulfur.*

Green manuring (GM)	**Dry matter production at Post-anthesis (g m^{-2})**			
	Total	Stem	Leaves	Head
No green manuring	1033 b	423 b	256 b	354 b
Berseem green manuring	1175 a	479 a	296 a	401 a
Significance	**	**	**	**
Nitrogen (N) (kg ha^{-1})				
0	1005 d	412 d	250 c	342 d
60	1066 c	436 c	265 b	365 c
90	1149 b	467 b	292 a	390 b
120	1197 a	489 a	295 a	413 a
$LSD_{(P=5\%)}$	42	17	15	14
Sulfur (S) (kg ha^{-1})				
0	1012 d	413 d	252d	347 d
15	1068 c	438 c	264 c	366 c
30	1141 b	468 b	283 b	390 b
45	1196 a	485 a	304 a	407 a
$LSD_{(P=5\%)}$	42	17	15	14
Interactions	**Significance**			
GM x N	*	NS	*	*
GM x S	NS	NS	NS	NS
N x S	NS	NS	NS	NS
GM x N x S	NS	NS	NS	NS

Means of each category followed by same letters are statistically at par with each other at 5% level of probability . "" = significant at 5% level of probability, "**" = significant at 1% level of probability, "NS" = Non-significant*

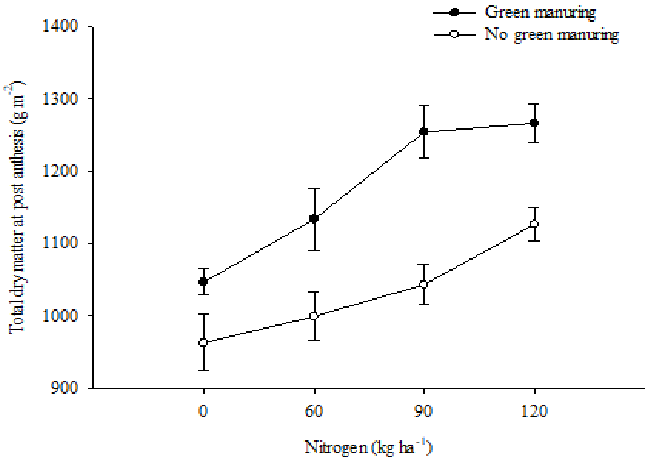

Figure 3: *Interactive effect of green manuring and nitrogen on total dry matter accumulation at post-harvest*

Green manuring, nitrogen and sulfur revealed substantial effect on stem dry matter at post-harvest All the interactions were insignificant for stem dry matter at post-harvest. Green manuring with berseem improved stem dry matter at post-harvest (479 g m^{-2}) as compared to no green manuring (423 g m^{-2}). Increasing nitrogen levels increased stem dry matter at post-harvest. Higher stem dry matter (489 g m^{-2}) was produced with 120 kg N ha^{-1}. Minimum (412 g m^{-2}) stem dry matter was recorded with no N application. Similar to nitrogen, increasing sulfur levels also increased stem dry matter at post-harvest. Higher stem dry matter at post-harvest (485 g m^{-2}) was obtained with addition of 45 kg S ha^{-1}. Minimum stem dry matter (413 g m^{-2}) was produced with no sulfur application.

Green manuring, nitrogen and sulfur levels had noteworthy impact on leaf dry matter production at post-harvest. The GM×N interaction was found significant only. Green manuring with berseem crop produced higher leaf dry matter (296 g m^{-2}) as compared to no green manuring (256 g m^{-2}). Among different nitrogen levels, increasing nitrogen from 0 to 90 kgha^{-1} linearly increased dry matter accumulation in leaves at post-harvest. Greater dry matter (295 g m^{-2}) was accumulated in leaves with using 120 kg N ha^{-1}, statistically alike results were obtained with leaf dry matter (292 g m^{-2}) produced with 90 kg N ha^{-1}. Minimum leaf dry matter at post-harvest (250 g m^{-2}) was produced with no N application. Application of 45 kg sulfur ha^{-1} accumulated more dry matter (304 g m^{-2}) to leaves. Minimum leaf dry matter (252 g m^{-2}) was produced by control. The interaction between GM×N indicated that raising

N levels upto 120 kg ha^{-1} increased leaf dry matter production with or without green manuring, however with green manuring a slight decreased was observed with increasing nitrogen beyond 90 kg ha^{-1} (Figure 4).

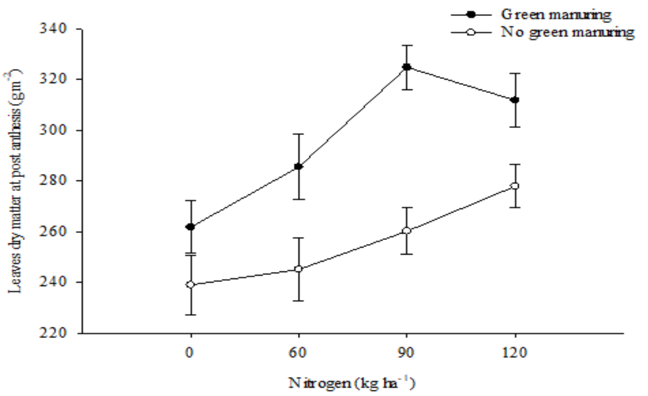

Figure 4: *Interactive effect of green manuring and nitrogen on dry matter accumulation in leaf at post-harvest*

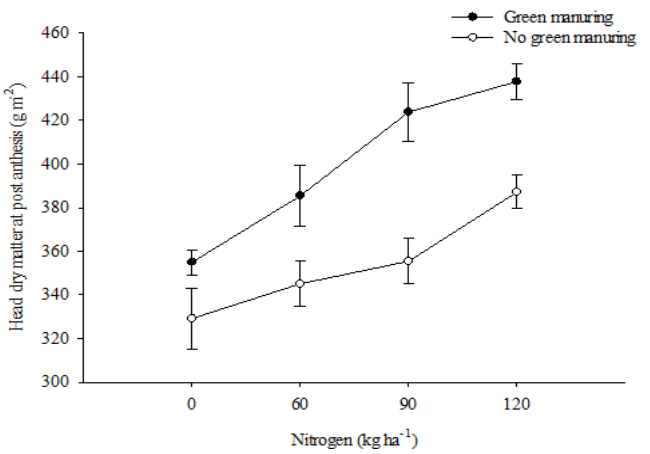

Figure 5: *Interactive effect of green manuring and nitrogen on head dry matter at post-harvest*

Head dry matter accumulation was meaningfully affected by green manuring, nitrogen and sulfur. GM×N interaction was found significant and the remaining were non-significant. Green manuring with berseem produced higher head dry matter (401 g m^{-2}) as compared to no green manuring (354 g m^{-2}). Head dry matter was increased with each increment in nitrogen level. Dry matter accumulation in heads (413 g m^{-2}) was greater with using 120 kg N ha^{-1}. Dry weight of heads were lower (342 g m^{-2}) with no nitrogen application. Similarly increasing sulfur level increased head dry matter at post-harvest stage consistently. Addition of 45 kg S ha^{-1} accumulated more (407 g m^{-2}) head dry matter. No sulfur application produced minimum head dry matter (347 g m^{-2}). The interaction between GM×N exhibits that increasing nitrogen level from 0 to 90 kg ha^{-1} increased head dry matter irrespective of green manuring, however further increase in nitrogen did not increase head dry matter with green manuring and increase head dry matter with no green manuring (Figure 5).

Table 3: *Biological yield (kg ha^{-1}) of sunflower as affected by green manuring, nitrogen and sulfur levels.*

Green manuring	Year		Means
	2019	2020	
No green manuring	9017	9907	9462 b
Berseem green manuring	10437	11385	10911 a
Significance			**
Nitrogen (N) (kg ha^{-1})			
0	8738	9632	9185 d
60	9341	10243	9792 c
90	10146	11082	10614 b
120	10685	11629	11157 a
$LSD_{(P=5\%)}$			368
Sulfur (S) (kg ha^{-1})			
0	8814	9702	9258 d
15	9410	10324	9867 c
30	10082	11031	10556 b
45	10604	11528	11066 a
$LSD_{(P=5\%)}$			368
Year means	9727	10646	**
Interactions	Significance	Interactions	Significance
GM×N	*	GM×N×S	NS
GM×S	NS	Y×T	NS
N×S	NS		

Means of each category followed by same letters are statistically at par with each other at 5% level of probability . "" = significant at 5% level of probability, "**" = significant at 1% level of probability, "NS" = Non-significant*

Total yield (kg ha^{-1})

Total yield of sunflower as influenced by different green manuring, nitrogen and sulfur levels is shown in Table 3. Statistical analysis of the recorded data showed that total yield of sunflower was considerably affected by different green manuring, nitrogen and sulfur levels. The interaction between green manuring and nitrogen (GM×N) was the only significant interaction among all the possible interactions. Green manuring of berseem crop produced higher total yield (10911 kg ha^{-1}) as compared to no green manuring (9462 kg ha^{-1}). In case of nitrogen levels, total yield was increased linearly with increasing nitrogen level up to 120 kg ha^{-1}. Highest total yield (11157 kg ha^{-1})

was recorded with 120 kg nitrogen ha^{-1}, which was followed by 90 kg ha^{-1} (10614 kg ha^{-1}). Minimum total yield (9185 kg ha^{-1}) was obtained with no nitrogen application. Among different levels of sulfur, sulfur application at the rate of 45 kg ha^{-1} produced greater total yield (11066 kg ha^{-1}), followed by 30 kg S ha^{-1} (10656 kg ha^{-1}). Minimum total yield (9258 kg ha^{-1}) was obtained with no sulfur application. The interaction between GM×N indicated that increasing nitrogen level linearly increased total yield with no green manuring, however the increase was linear up to 90 kg N ha^{-1} and beyond that no further increase was found (Figure 6).

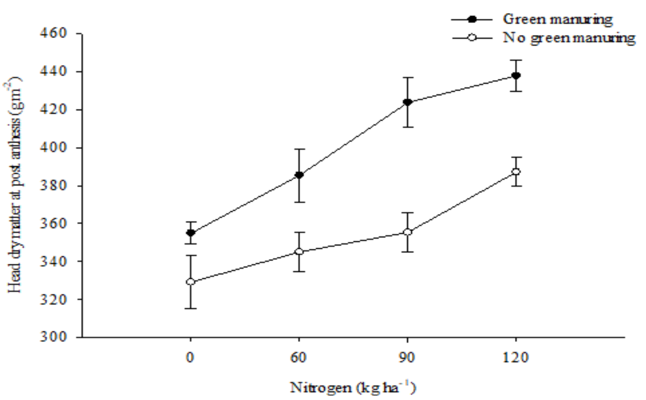

Figure 6: *Interactive effect of green manuring and nitrogen on biological yield of sunflower*

Discussion

Green manuring significantly improved crop growth rate and dry matter (DM) accumulation and assimilates partitioning. Assimilates partitioning was significantly different at different stages. Higher dry matter accumulation in vegetative parts at pre-anthesis stage and at maturity stages as assimilates partitioning were higher to reproductive parts. Green manuring improved stem, leaves and head dry matter as compared to no green manuring. The improvement in dry matter production with green manuring might be due to the ability of green manures to provide sufficient nutrients to the plants and improve soil properties. Baiyeri and Tenkouano (2007) reported similar trend and stated that green manuring enhanced properties of soil and soil fertility which lead to improvement in photosynthetic efficiency and assimilates partitioning. Moreover, Ayeni and Adetunji (2010) also stated that green manuring supply essential nutrients to crop which enhanced the DM production that lead to higher DM accumulation. Application of green manuring together with nitrogen fertilizer will balance carbon and nitrogen in soil and plants can uptake nitrogen requirement and other nutrients from soil (Mosavi *et al*., 2009). Amanullah *et al*. (2006) described that green manuring and harmonization of nutrients release at appropriate stage of crop growth resulted in improvement in growth rate, dry matter production as well as leaf area. These results are in line with Lenka and Gulati (2005) and Ronanki *et al*. (2017).

Nitrogen application improve crop growth rate (CGR) and dry matter (DM) production. The probable reason for improvement in DM production and CGR with nitrogen fertilization is the ability of nitrogen to increase light interception, photosynthetic efficiency and transfer of assimilates (Shekhawat and Shivay, 2012). In contrast poor nitrogen availability to plants resulted in reduced photosynthetic ability, and decrease in assimilates production which leads to lower crop growth and dry matter production (Osterhuis and Zhao, 2006). Current findings are in line with findings described by Dordas and Siolas (2009) who reported higher crop growth rate, photosynthates and dry matter with increasing level of nitrogen rates. Dreccer *et al*. (2000) also resulted in an increase in dry matter yield with application of nitrogen.

Sulfur levels significantly varied CGR and DM production. Increasing sulfur levels increased CGR and dry matter production. Which could be attributed to boost photosynthesis accumulation. Sulfur is constituent of enzymes which is involved in chlorophyll production and activating cellular level of accelerated photosynthesis (Deepika *et al*., 2022). Thus resulting in more dry matter accumulation. Our findings are alike with the results mentioned by Ramu and Reddy (2003) and Sarkar and Mallick (2009) who reported increased dry matter with application of sulfur. Moreover Daniela *et al*. (2008) stated that sulfur application significantly increased crop growth rate.

Yield of sunflower was considerably affected by green manuring, nitrogen and sulfur levels. Green manuring with berseem crop improved yield as compared to no green manuring. The improvement in yield due to green manuring might be due to the nutrient supply and soil fertility executed by green manuring. Hemalatha *et al*. (2000) observed a profound increment in yield with green manuring of legumes. The reason for rise in various growth traits might be enhanced nutrients uptake and making the nutrients translocated to plant body, sufficient nutrient supply increased photosynthates production and translocation to the sink, which resulted in higher plant growth and growth attributes (Dambale *et al*., 2018). Nitrogen application increased yield of sunflower. Application of 120 kg N ha^{-1} improves all the growth attributes. This is the ability of the plants to access the soil nitrogen more frequently which resulted in higher reproductive growth and production of plant parts, hence increased nitrogen consumption by absorbing more nutrients. Utilization of greater quantity of nitrogen under optimum growing conditions is essential to flourish crop, which increase yield. Increasing nitrogen fertilizer leads to increase in yield (Zubillaga *et al*., 2002; Wajid *et al*., 2010; Zahoor *et al*., 2010). Significant effect of nitrogen was observed on yield and oil content (Abbadi and Gerendas, 2009; Wajid *et al*., 2010; Ahmad *et al*., 2020).

Sulfur application increase yield of sunflower and higher yield were obtained with addition of 45 kg S ha^{-1}. Parallel results were earlier reported regarding the effect of sulfur on yield by Ullah and Akmal (2018) who reported profound effects of sulfur application when combined with nitrogen on plant parameters. Saleem *et al*. (2019) reported in a similar study on response of sulfur on sunflower that addition of 20 kg S ha^{-1} along with zinc increased the yield of sunflower.

Conclusions and Recommendatoins

The research demonstrates that nitrogen sulphur and green manuring play a critical part in improving dry matter production and partitioning to various plant as well as total yield of sunflower. Green manuring with berseem crop significantly improved dry matter partitioning and yield of sunflower. Nitrogen and sulphur levels significantly enhanced dry matter partitioning and yield. Application of 30 kg S and 120 kg N ha^{-1} improved dry matter partitioning and yield. Therefore, is recommended as a balanced approach to nutrient management along with green manuring to improve sunflower growth and yield.

Novelty Statement

The novelty of the study lies in elucidating the influence of integrated green manuring and nutrient management on pre and post anthesis dry matter partitioning in sunflower, offering new understanding of biomass allocation patterns under sustainable fertility practices.

Author's Contribution

Bilal Khan: Data curation, investi-gation, formal analy-sis, software, writing draft
Asad Ali Khan: Conceptualization, supervision, project administration.
Amanullah: Validation, review and editing
Dost Muhammad: Methodology, supervision, resources

Generative AI or AI assisted technology statement
The authors have declared that no generative AI or AI-assisted technologies were used to create this manuscript.

Conflict of interest
The authors have no conflict of interest.

References

Abbadi, J. and J. Gerendas. 2009. Nitrogen use efficiency of safflower as compared to sunflower. *J. Plant Nutr.*, 32(6): 929–945. https://doi.org/10.1080/01904160902870705

Acs, P.B., B.E. Andras, S. Mondici, M. Cergan, P.A. Ursan and I. Pacurar. 2025. Green manure: a sustainable solution for enhancing fertility and reducing acidity in Albic Luvisols fo Northwestern Romani. Roman. Agric. Res., 42: 561-575. https://doi.org/10.59665/rar4248

Adeleke, B.S. and O.O. Babalola. 2020. Oilseed crop sunflower (*Helianthus annuus*) as a source of food: Nutritional and health benefits. *Food Sci. Nutr.*, 8(9): 4666–4684. https://doi.org/10.1002/fsn3.1783

Ahmad, S., A. Ghaffar, M.A. Khan and A. Mahmood. 2020. Evaluation of different production systems in combination with foliar sulphur application for sunflower (*Helianthus annuus* L.) under arid climatic conditions of Pakistan. Sarhad J. Agric., 36(4): 1266-1278. https://doi.org/10.17582/journal.sja/2020/36.4.1266.1278

Amanullah, M.M., M.M. Yasin, E. Somasundaram, K. Vaiypapuri and K. Sathyamoorthi. 2006. N availability in fresh and composted poultry manure. Res. J. Agric. Biol. Sci., 2(6): 406–412.

Asif, M., M.E. Safdar, N. Akhtar, S. Gul, M.A. Javed, N. Raza, I. Haq, U. Saleem and M.

Aslam. 2023. Sulfur application improves the yield and quality of sunflower (*Helianthus Annuus* L.) hybrids. Sabrao J. Breed. Genet., 55(3): 907-916. https://doi.org/10.54910/sabrao2023.55.3.25

Ayeni, L.S. and M.T. Adetunji. 2010. Integrated application of poultry manure and mineral fertilizer on soil chemical properties, nutrient uptake, yield and growth components of maize. Nature Sci., 8(1): 60–67.

Baiyeri, K.P. and A. Tenkouano. 2007. Manure placement influenced growth and dry matter yield of a plantain hybrid. Afr. Crop Sci. Conf. Proc., 8: 385–390.

Chen, X., H. Zhang, C. Zhou, A. Teng, L. Lei, Y. Ba, F. Li and H. Li. 2025. Optimizing water-nitrogen management enhances sunflower productivity and seed quality while mitigating soil nitrogen residues in a cold and arid environment. Plant Soil., pp. 1-25. https://doi.org/10.1007/s11104-025-07597-y

Dambale, A.S., A.K. Ghotmukale, S.B. Suryawanshi, V. Suryavanshi and S.D. Khandekar. 2018. Growth and yield of sunflower as influenced by integrated application of organic and inorganic fertilizers (*Helianthus annuus* L.). J. Agric. Res. Technol., 43(1): 5.

Daniela, O., S. Pietkiewicz, M. Ciesinski, K. Kucinska and G. Gowsdozki. 2008. Biomass accumulation and absorption of photosynthetic active radiation by rapeseed depending on sulfur fertilization. World J. Agric. Sci., 4: 133–136.

Debaeke, P., F. Attia, L. Champolivier, J.F. Dejoux, A. Micheneau, A. Al Bitar and R. Trépos. 2023. Forecasting sunflower grain yield using remote sensing data and statistical models. *Eur. J. Agron.*, 142: 126677. https://doi.org/10.1016/j.eja.2022.126677

Deepika, C.L., D.R. Singh and E. Singh. 2022. Effect of nitrogen and sulfur levels on growth and yield of sunflower (*Helianthus annuus* L.). *Pharma Innov. J.*, 11(3): 2049–2052.

Dordas, C.A. and C. Sioulas. 2009. Dry matter and nitrogen accumulation, partitioning and retranslocation in safflower (*Carthamus tinctorius* L.) as affected by nitrogen fertilization. Field Crops Res., 110(1): 35–43. https://doi.org/10.1016/j.fcr.2008.06.011

Dreccer, M.F., M.V. Oijen, A.H.C.M. Schapendonk, C.S. Pot and R. Rabbinge. 2000. Dynamics of vertical leaf nitrogen distribution in a vegetative wheat canopy. Impact on canopy photosynthesis. Ann. Bot., 86(4): 821–831. https://doi.org/10.1006/anbo.2000.1244

Fanish, S.A. 2018. Effect of green manuring on plant health. World J. Agric. Sci., 14(1): 1–12.

Hemalatha, M., V. Thirumugan and R. Balasubramanian. 2000. Effect of organic sources of nitrogen on productivity and quality of rice (*Oryza sativa*) and soil fertility. *Ind. J. Agron.*, 45(3): 564–567. https://doi.org/10.59797/ija.v45i3.3415

Hussain, S., A. Khalil, A. Qayyum, S.U. Khan, A. Mehmood, G. Ahmad, A.H. Ghazy, A.A. Al-Doss, K.A. Attia and Y. Zeng. 2025. Optimizing sunflower (*Helianthus annuus* L.) hybrids growth, achene and oil yield through soil applied sulphur and zinc. Scien. Rep., 15(1): 13829. https://doi.org/10.1038/s41598-025-96800-2

Indu, T. and R. Singh. 2020. Effect of sulphur and boron on growth and yield of sunflower (*Helianthus annuus* L.). *Int. J. Curr. Microbiol. App. Sci.*, 9(8): 3320–3323. https://doi.org/10.20546/ijcmas.2020.908.381

Jan, M.T., P. Shah, P.A. Hollington, M.J. Khan and Q. Sohail. 2009. Agriculture research: design and analysis, a monograph. NWFP Agric. Univ. Pesh., Pak., 1: 232.

Javaid, K., A. Mahmood, H.F.N Alawadi, M.S. Ullah, M.F. Seleiman, M. Ameen, A. Asghar and N. Ali. 2024. Synergic effect of sulfur and nitrogen on morpho-physiological and biochemical traits of sunflower. Notu. Bot. Hort. Agrobot. Cluj-Nap., 52(2): 13584-12584. https://doi.org/10.15835/nbha52213584

Kalaiyarasan, C., D. Tamizhselvan, S. Jawahar, S. Ezhilkumar, K. Suseendran, S. Madhavan and S. Ramesh. 2020. Effect of sulphur and boron on hybrid sunflower. *Plant Arch.*, 20(1): 741–746.

Kamran, M., M. Zhang, Q. Jia, M. Usman, M. Waris, S. Chang and F. Hou. 2025. Legume-grass intercropping at low nitrogen input: Achieving the dual goals of lower greenhouse gas emissions and high quality forage productivity in the arid region. Agric. Ecosys. Env., 393: 109859. https://doi.org/10.1016/j.agee.2025.109859

Lenka, S. and J.M.L. Gulati. 2005. Growth parameters, tiller dynamics, dry matter accumulation and its partitioning in rice cultivars as influenced by methods of establishment under aerobic and anaerobic conditions. Environ. Ecol., 33(4): 1448–1453.

Mahboob, W., G. Yang and M. Irfan. 2023. Crop nitrogen (N) utilization mechanism and strategies to improve N use efficiency. *Acta Physiol. Plant.*, 45(4): 52. https://doi.org/10.1007/s11738-023-03527-6

MNFSR. 2023. Ministry of National Food Security and Research. Agricultural Statistics of Pakistan. *Yearly Book.*

Mosavi, S.B., A.A. Jafarzadeh, M.R. Neishabouri, S. Ostan and V. Feiziasl. 2009. Rye green manure along with nitrogen fertilizer application increases wheat (*Triticum aestivum* L.) production under dryland condition. Int. J. Agric. Res., 4(6): 204–212. https://doi.org/10.3923/ijar.2009.204.212

Nguyen, P.V., R.W. McDowell and L.M. Condron. 2024. Impact of green manure crop species on rhizosphere soil phosphorus. Soil Res., 62(5). https://doi.org/10.1071/SR22257

Osterhuis, D.M. and D. Zhao. 2006. Effect of B deficiency on the growth and carbohydrate metabolism of cotton. Dev. Plant Sci. Soil Sci., 92: 166–167. https://doi.org/10.1007/0-306-47624-X_80

Rahangdale, P., A.K. Thakur and A. Kumar. 2024. Response of planting geometry, nitrogen and sulphur levels on growth parameters and yield of sunflower (*Helianthus annus* L.). Plant Arch., 24(2).

Ramu, Y.R. and P.M. Reddy. 2003. Growth and yield of sunflower as influenced by nitrogen and sulfur nutrition. *Indian J. Dryland Agric. Res. Dev.*, 18(2): 192–195.

Ren, W., X. Li, T. Liu, N. Chen, M. Xin, Q. Qi and B. Liu. 2025. Controlled-release fertilizer affects leaf nitrogen allocation and photosynthesis to improve nitrogen use efficiency and yield in sunflower field. Front. Plant Sci.,16: 1622766 https://doi.org/10.3389/fpls.2025.1622766

Ronanki, S., P. Leela Rani, A. Madhavi, G. Sreenivas and D. Raji Reddy. 2017. Dry matter accumulation, partitioning and nitrogen uptake of transplanted rice under varied plant densities and nitrogen levels. Chem. Sci. Rev. Lett., 6(23): 1975–1979.

Saleem, M., E. Elahi, A.W. Gandahi, S.M. Bhatti, I. Hajra and M.A. Shaikh. 2019. Effect of sulphur application on growth, oil content and yield of sunflower. Sarhad J. Agric., 35(4): 1198-1203. https://doi.org/10.17582/journal.sja/2019/35.4.1198.1203

Sarkar, R.K. and R.B. Mallick. 2009. Effect of nitrogen, sulfur and foliar spray of nitrate salts on performance of spring sunflower (*Helianthus annuus*). *Ind. J. Agric. Sci.*, 79(12): 986–990.

Shekhawat, K. and Y.S. Shivay. 2012. Residual effects of nitrogen sources, sulfur and boron levels on mungbean (*Vigna radiata*) in a sunflower (*Helianthus annuus*)–mungbean system. Arch. Agron. Soil Sci., 58(7): 765–776 https://doi.org/10.1080/03650340.2010.546786.

Sher, A., M. Suleman, A. Sattar, A. Qayyum, M. Ijaz, S.U. Allah and M.S. Elshikh. 2022. Achene yield and oil quality of diverse sunflower (*Helianthus annuus* L.) hybrids are affected by different irrigation sources. *J. King Saud Univ. Sci.*, 34(4): 102016. https://doi.org/10.1016/j.jksus.2022.102016

Ullah, S. and M. Akmal. 2018. Response of sunflower to integrated management of nitrogen, phosphorus and Sulphur. Sar. J. Agric., 34(4): 740-748 https://doi.org/10.17582/journal.sja/2018/34.4.740.748

Wajid, A., A. Ahmad, T. Khaliq, S. Alam, A. Hussain, K. Hussain, W. Nasim, M. Usman and S. Ahmad. 2010. Quantification of growth, yield and radiation use efficiency of promising cotton cultivars at varying nitrogen levels. *Pak. J. Bot.*, 42(3): 1703–1711.

Zahoor, A., M. Riaz, S. Ahmad, H. Ali, M.B. Khan, K. Javed, M.A. Anjum, M. Zia-ul-Haq and M.A. Khan. 2010. Ontogeny growth and radiation use efficiency of *Helianthus annuus* L. as affected by hybrids, nitrogenous regimes and planting geometry under irrigated arid conditions. *Pak. J. Bot.*, 42(5): 3197–3207.

Zhao, N., L. Bai, D. Han, Z. Yao, X. Liu, Y. Hao, Z. Chen, X. Zhang, D. Zhang, X. Jin and Z. Wang. 2024. Combined application of leguminous green manure and straw determined grain yield and nutrient use efficiency in wheat–maize–sunflower rotations system in Northwest China. Plant., 13(10): 1358. https://doi.org/10.3390/plants13101358

Zubillaga, M.M., J.P. Aristi and R.S. Lavado. 2002. Effect of phosphorus and nitrogen fertilization on sunflower (*Helianthus annuus* L.) nitrogen uptake and yield. *J. Agron. Crop Sci.*, 188(4): 267–274. https://doi.org/10.1046/j.1439-037X.2002.00570.x