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Research Article

Effect of varieties and fertilizer levels combined with biofertilizers on growth and yield of sunflower (*Helianthus annuus* L.) in Chitwan, Nepal

Sagar Dhakal*, Aashish Bandhu Aryal, Aakriti Poudel, Bibek Aryal, Bishnu Bilas Adhikari

Institute of Agriculture and Animal Science, Tribhuvan University, Rampur Campus, Nepal
*Correspondence: dhakalsagar283@gmail.com, ORCID: https://orcid.org/0009-0008-2031-269X

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ABSTRACT
At the Rampur Campus research farm in Khairahani, Nepal, a field experiment was carried out in the spring of 2022–2023 to assess the effects of sunflower varieties and fertilizer treatments combined with biofertilizers on growth and yield. A two-factor Randomized Complete Block Design with three replications was used in this study. Two sunflower varieties, namely Sungold-753 and Bharat-709 along with five fertilizer treatments namely F1 – 80:100:60 kg NPK/ha + phosphate-solubilizing bacteria (PSB) and potash-solubilizing bacteria (KSB); F2 – 60:80:40 kg NPK/ha + PSB and KSB; F3 – 40:60:20 kg NPK/ha + PSB and KSB; F4 – 20:40:10 kg NPK /ha + PSB and KSB; and F5 – control. The findings showed that neither variety nor fertilizer treatment had a significant impact on plant height or days to maturity. On the other hand, under the maximum fertilizer dose (80:100:60 kg NPK/ha) combined with PSB and KSB, the leaf area index at 60 days after planting was significantly higher (5.67). Additionally, the largest capitulum weight per plant (175.85 g) was produced by the same treatment. Bharat-709 was the variety with the best grain yield (2.40 t/ha), while the treatment of 80:100:60 kg NPK/ha + biofertilizers produced the highest yield (3.12 t/ha). According to these results, growing Bharat-709 with 80:100:60 kg NPK/ha supplemented with PSB and KSB is a successful method for maximizing sunflower yield in Chitwan, Nepal's agroclimatic conditions.

Keywords: Sunflower, Varieties, Biofertilizers, NPK Fertilizer, Yield

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INTRODUCTION
Oilseed crops are important in the farming systems and especially in the case of the poor who cannot afford to buy major cereals or cash crops. Their ability to grow even in poor soils makes them the right choice for areas that do not have traditional agriculture. Besides being a source of resilient cropping system case of oilseeds, oilseeds support nutritional security, yield less for the farmer, and are environmentally friendly, promote the use of less productive lands, and take part in the preservation of cultural heritage and traditional agricultural practices. In a global context, oilseed crops are part of the solution to the problems of food security, nutrition, and economic resilience (FAO, 2020). The contribution of agriculture to national GDP in Nepal is approximately 25.8%, and the oilseed subsector contributes about 3% of Agricultural GDP and 0.77% of overall GDP (Ministry of Agriculture and Livestock

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Development, 2020), thus indicating their important contribution to rural livelihoods and sectoral diversification.

Sunflower is among the main oilseed crops that are appreciated for its high-quality edible oil and many other properties such as early maturity, growing in different climates and soils, drought tolerance, and producing more under improved management (Patra, 2013; Namvar, 2012). Nutritionally, sunflower oil is rich in, especially in linoleic acid, and the seeds of the crop plus by-products have various food, industrial and medicinal uses (Kumar *et al.*, 2019; Dhandapani & Nadu, 2012). Sunflower is globally the third most cultivated oilseed after soybeans and peanuts with the biggest producers being Russia, Ukraine, and Argentina (Fernández-Luqueño et al., 2014). In Nepal, the sunflower is grown over an area of 3,688 hectares, yielding 4,834 metric tons of seeds, with an average productivity of 1.31 tons per hectare: the area of the Chitwan district is 12 hectares, which with the yield of 21 metric tons, hints at the possibility of increasing productivity. The situation in Nepal regarding sunflowers has taken a toll due to various factors like the non-usage of hybrid varieties, and the unplanned nutrient management which altogether contributes to the poor productivity of sunflowers in Nepal. The traditional fertilization methods seldom fulfil the nutrient requirement of the crops and the research on integrated methods of chemical fertilizers with biofertilizers is also very minute. Biofertilizers such as Azotobacter, Azospirillum, PSB, and KSB can make the nutrients available in the soil, facilitating plant growth, improving the health of the soil, and reducing the use of chemicals (Jayathilake, 2006; Rodríguez & Fraga, 1999). Research examining the effects of not only improved sunflower varieties but also Bio-fertilizer-assisted-nutrient management is very important for the development of cost-effective, sustainable, and high-yielding cultivation practices that are suitable for Nepalese conditions. This study was intended to (I) determine the growth and yield performance of sunflower varieties under the different fertilizer regimes supplemented with bio-fertilizers and (II) find out the best nutrient management strategy for Chitwan, Nepal's Agri-climatic conditions that would, in turn, lead to better sunflower productivity. The research offers practical recommendations for sustainable sunflower production by filling these gaps, which in turn, will contribute to increased food security, farmers' incomes, and optimal land use.

MATERIALS AND METHODS

Experimental site

The experiment was carried out at the Agronomy Farm of IAAS, Rampur Campus, Khairahani, Chitwan, which is situated about 17 km east of Bharatpur, Chitwan, Nepal, at latitude 27°60'N, longitude 84°56'E, and altitude 184 meters above sea level. The research site has a year-round tropical monsoon climate with high humidity. Usually starting in the middle of June, the monsoon season lasts until late September. After mid-October, everyday temperatures progressively drop from about 36°C to 18°C, the monsoon clouds decrease and humidity decreases. It can get as low as 5°C at night until late December, when there is occasional light rain. The following months show a gradual increase in temperature.

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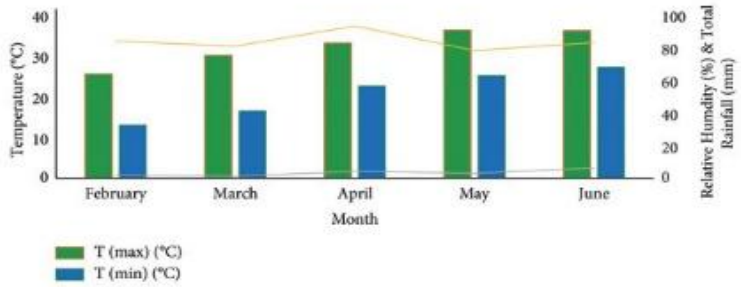

Figure 1: Temperature and Relative Humidity status during cropping period

Treatment details

The treatment details is given in Table 1.

Table 1: Details of treatments used in the study at Khairahani

Treatment symbol	Treatments
T_1	Bharat709 + 80:100:60kg NPK/ha +Bio fertilizer solution
T_2	Bharat 709 + 60: 80: 40 kg NPK/ha + Biofertilizer solution
T_3	Bharat 709 + 40: 60: 20 kg NPK/ha + Biofertilizer solution.
T_4	Bharat 709 + 20: 40: 10 kg NPK/ha + No biofertilizer solution
T_5	Bharat 709 + No fertilizers
T_6	Sungold 753 + 80: 100: 60 kg NPK/ha + Biofertilizer solution
T_7	Sungold 753 + 60: 80: 40 kg NPK/ha + Biofertilizer solution
T_8	Sungold 753 + 40: 60: 20 kg NPK/ha + Biofertilizer solution
T_9	Sungold 753+ 20: 40: 10 kg NPK/ha + No biofertilizer solution
T_{10}	Sungold 753 + No fertilizer

Crop management

The site for the experiment was made ready by deep ploughing which raised the soil aeration and drainage to a better level, followed by a couple of tillage operations: one was a spring tine cultivator and at 7th Falgun, the other was a disk harrow two days later, making the field ready for sowing on 14th Falgun 2079. Two hybrids of sunflower, Bharat 709 and Sungold 753, were taken, having more than 98% genetic and physical purity, and less than 6% moisture, and the seeds were treated with thiram/captan beforehand. Organic manure (FYM) was given at the time of sowing, and chemical fertilizers-urea (46% N), DAP (18% N, 46% P_2O_5), and MOP (60% K_2O)-were used, with full P and K and half N at sowing, and the rest of N in two splits at bud formation and flowering stages. Biofertilizers (KSB and PSB) were given in a solution made with jaggery every 15 days. Each plot measured 3 m × 2 m (6 m^2), with five rows of five plants each, maintaining 60 cm row spacing and 40 cm plant spacing. Two seeds per hill were manually sown on 14th Falgun 2079, followed by gap filling on 24th Falgun and thinning after 30 days on 27th Chaitra to maintain one plant per hill. The irrigation was first applied eight days after sowing and later through furrows when the height of the plants reached 4-6 cm. Weed management was done by manually removing the weeds before thinning and a second removal using a sickle. Pest control was carried out using two sprays of King Killer (Chlorpyrifos 50% + Cypermethrin 5%) on 8th and 27th Chaitra 2079. Harvesting the crop was done when the back of the heads turned lemon yellow, starting from 26th Falgun 2079 onwards. Cutting, drying in the sun, and threshing were the methods used to separate the seeds from the flower heads (disks). Stalks were cut and their weight was

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measured.

Data collection

There were five rows of plants in each plot. The three central plants from the two inner rows were tagged and observed during the crop growing period to collect data. Data on growth, phenological, yield, and yield-attributing characters were recorded. A scale was used to measure the length of five leaves on each tagged plant, and the average value was computed. A single leaf was measured at its base, middle, and tip, and the results were averaged to get the leaf diameter. Next, leaf length and average leaf diameter were multiplied for estimating leaf area. Regular visual observation was used to collect data on 50% bud formation, 100% bud formation, first flower opening, 50% flower opening, and 100% flower opening. On harvested flower heads of tagged plants, the disk diameter was measured diagonally, and the average value was recorded. A weighing balance was used to measure the disk weight, and each sample's mean weight was computed.

Statistical analysis

Microsoft Excel 2019 was used to compile the data gathered from the experimental plots for each parameter, and GENSTAT Version 24.1 was used for analysis. The coefficient of variation (CV), least significant difference (LSD (0.5)), standard error of the mean (SEM) was all calculated as part of the analysis. Differences among treatment means were tested for significance using Duncan's Multiple Range Test (DMRT) at a 5% probability level ($p \leq 0.05$).

RESULTS AND DISCUSSION

Plant height

The variety "Bharat 709" with the 80:100:60 kg NPK/ha + BF treatment produced a maximum plant height of 27.28 cm and 28.36 cm at 30 days after sowing (DAS).

Table 2: Effect of different varieties and levels of fertilizers with bio fertilizer on plant height of Sunflower at Khairahani Chitwan during 2023

Treatments	Pant height (cm)		
Variety (V)	30 DAS	45 DAS	60 DAS
Bharat709	27.28	89.08	136.27
Sungold 753	26.29	97.46	150.02
LSD (0.5)	3.71	9.59	20.05
SEM (±)	5.57	537.34	163.15
F-test	NS	NS	NS
CV%	8.8	6.6	8.9
Levels of fertilizer			
80: 100: 60 kg NPK /ha +BF	28.36	99.17	150.90
60: 80: 40 kg NPK /ha + BF	25.95	87.89	140.79
40: 60: 20 kg NPK /ha + BF	26.48	96.03	140.30
20: 40: 10 kg NPK /ha + BF	28.13	93.13	140.55
Control (no fertilizers)	25.02	90.11	143.22
LSD (0.5)	6.08	7.68	18.55
SEM (±)	11.46	204.94	217.59
F-test	NS	NS	NS
CV%	12.60	15.30	10.30
Grand mean	26.78	93.27	143.15

NS: Not significant, LSD: Least significant difference, CV: Coefficient of variation

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Under the same NPK + BF treatment, the Sungold 753 variety showed the highest plant height of 97.46 cm and 99.17 cm at 45 DAS. In Sungold 753 with 80:100:60 kg NPK/ha + BF, the tallest plants, measuring 150.02 cm and 150.90 cm, were measured at 60 DAS. Higher NPK levels resulted in a considerable increase in plant height. Increased plant height was achieved by prolonging the growth period with higher NPK levels. According to the results of Škorić *et al.* (2007), Handayati and Sihombing (2019), and Bakht *et al.* (2010), higher amounts of nitrogen and phosphorus stimulate cell division, multiplication, and elongation, which promotes early vegetative growth. Additionally, the combination application of NPK and biofertilizer had a considerable impact on plant height. Although it did not differ significantly from other higher treatments, the maximum nitrogen application rate (80:100:60 kg NPK/ha + PSB and KSB) produced the highest height. In the control, the lowest plant height was noted. These findings are consistent with those of (Fakirah & Al-thobhani, 2017). The findings revealed that the interaction of both NPK amounts and varieties along with biofertilizer had a significant impact on the leaf area index (LAI) at 60 DAS. Bharat-709 among the varieties had LAI of 0.37, 1.49, and 0.59 at 30, 45, and 60 DAS, respectively, while Sungold-753 showed 0.49, 2.05, and 0.02 at the growth stages mentioned earlier. The difference between the two was significant at 60 DAS ($p \leq 0.05$), but not at 30 and 45 DAS.

Table 3: Effect of different varieties and levels of fertilizers with bio fertilizer on leaf area index of sunflower at Khairahani Chitwan during 2023

Variety	30 DAS	45 DAS	60 DAS
Bharat-709	0.37	1.49	0.59[b]
Sungold-753	0.49	2.05	0.02[a]
LSD (0.5)	0.31	0.76	0.95
SEM (±)	0.03	0.22	0.36
F-test	NS	NS	*
CV%	46.2	26.4	14
Levels of fertilizers			
80: 100: 60 kg NPK /ha +BF	0.53	2.37	5.67[a]
60: 80: 40 kg NPK /ha + BF	0.35	1.69	4.32[b]
40: 60: 20 kg NPK /ha + BF	0.37	1.40	3.57[b]
20: 40: 10 kg NPK /ha + BF	0.42	1.62	3.89[b]
Control (No Fertilizer)	0.49	1.77	4.09[b]
LSD (0.5)	0.16	0.65	1.13
SEM (±)	0.01	0.26	0.81
F-test	NS	NS	**
CV%	29.00	29.10	20.90
Grand mean	0.43	1.77	4.31

**Significant at 5% level of significance, ** significant at 1%level of significance, NS: Not significant, LSD: Least significant difference, CV: Coefficient of variation*

Khan *et al.* (2018) showed similar varietal variation in sunflower LAI, attributing variations to genetic potential and growth habits.In terms of fertilization rates, the maximum LAI (5.67 at 60 DAS) was reached at the rate of 80:100:60 kg NPK/ha + BF followed by 60:80:40 kg NPK/ha + BF (4.32), control (no fertilizer, 4.09), 20:40:10 kg NPK/ha + BF (3.89), and 40:60:20 kg NPK/ha + BF (3.57). The increased area of the plant's leaves was due to the higher and longer leaves because of the combination of higher NPK and biofertilizer application. The results agree with Khandekar *et al.* (2018), who reported that 100% N combined with *Azospirillum* and *Azotobacter* significantly increased leaf area index at 60 DAS compared to lower fertilizer levels. Enhanced nitrogen availability, which encourages

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leaf start, expansion, and chlorophyll synthesis, may be the cause of this increase in LAI (Marschner, 2012; Ahmad *et al*., 2019).

Phenological characters

Among two different varieties, Bharat 709 was the first to have 50% of its buds formed after 49.86 days, 100% after 56.06 days, and 50% of its flowers were open at the 53.80-day mark while the last one at 70.80 days. The Sungold variety had 50.00, 56.37, 53.60, and 69.80 days corresponding to its stages of development. No significant differences were found among the varieties for any of the phenological traits. Similar non-significant results in phenology have been reported by Khan *et al.* (2019), who noted that when genotypes are produced under uniform management practices, environmental conditions frequently have a greater influence on sunflower phenology than varietal differences.

Table 4: Effect of different varieties and different levels of fertilizers with bio fertilizer on reproductive/phenological characters of sunflower at Khairahani Chitwan during 2023

Treatment	Bud formation (50%)	Bud formation (100%)	Days to flower (50%)	Days to flower (100%)
Variety				
Bharat 709	49.86	56.06	53.80	70.80
Sungold 753	50.00	56.37	53.60	69.80
LSD (0.5)	0.75	1.24	2.27	3.37
SEM (±)	0.23	0.63	2.10	4.63
F-test	NS	NS	NS	NS
CV%	1.00	1.40	2.70	3.00
Fertilizers with biofertilizer				
80: 100: 60 kg NPK /ha + BF	50.83	57.00	53.50	70.16
60: 80: 40 kg NPK /ha + BF	49.66	55.33	54.50	72.00
40: 60: 20 kg NPK /ha + BF	49.66	56.67	52.50	67.83
20: 40: 10 kg NPK /ha + BF	49.5	56.00	53.83	69.5
Control (no fertilizers)	50	57.00	54.16	72.16
LSD (0.5)	1.83	1.84	1.37	2.66
SEM (±)	2.10	2.15	1.2	2.16
F-test	NS	NS	NS	*
CV%	2.90	2.60	2.00	3.00
Grand mean	49.90	56.40	53.70	70.33

**Significant at 5% level of significance, NS: Not significant, LSD: Least significant difference, CV: Coefficient of variation*

Regarding the levels of fertilizer applications, the control (no fertilizer) treatment exhibited the longest period to 100% flowering (72.16 days). This was followed by treatments of 60:80:40 kg NPK/ha + BF with 72.00 days, and 80:100:60 kg NPK/ha + BF with 70.16 days. The earliest 100% flowering was in the treatment with 40:60:20 kg NPK/ha + BF at 67.83 days. Days taken for 50% bud formation ranged from 49.5 days (20:40:10 kg NPK/ha + BF) to 50.83 days (80:100:60 kg NPK/ha + BF), while days taken for 100% bud formation ranged between 55.33 days (60:80:40 kg NPK/ha + BF) and 57.00 days (80:100:60 kg NPK/ha + BF and control). Similarly, days to 50% flowering varied from 52.50 days (40:60:20 kg NPK/ha + BF) to 54.50 days (60:80:40 kg NPK/ha + BF). The influence of fertilizer levels on the period to 100% flowering was significant, but the other phenological traits were not significantly affected by the treatments. Similar effects of nutrient availability on flowering timing have been reported in studies of crop phenology and sunflower nutrient response (Khaliq *et al.*, 2025).

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Yield attributing characters

The study's findings pointed out that not only the varieties but also the levels of fertilizers had a major impact on the head weight, while the head diameter was mainly affected by the fertilizer levels. Bharat 709 variety gave a higher head weight of 154.12 g when compared to Sungold 753 with 119.21 g, in contrast no significant difference was found in head diameter (12.43 cm for Bharat 709 and 12.59 cm for Sungold 753) between the two varieties. Similar non-significant differences in head diameter have been recorded in sunflower in previous studies, indicating that nutrition availability frequently has a greater impact on head size than genetic variation alone (Sarkar *et al*., 2020; Reddy & Kumar, 2018).

Table 5: Effect of different varieties and levels of fertilizers with bio-fertilizer on yield attributed characters of sunflower at Khairahani Chitwan during 2023

Treatments	Head diameter (cm)	Head weight (g)
Variety		
Bharat 709	12.43	154.12^{a}
Sungold 753	12.59	119.21^{b}
LSD (0.5)	0.47	8.85
F-test	0.09	31.80
F test	NS	**
CV%	2.4	4.1
Levels of fertilizers		
80: 100: 60 kg NPK /ha + BF	14.87^{a}	175.85^{a}
60: 80: 40 kg NPK /ha + BF	13.20^{ab}	140.44^{b}
40: 60: 20 kg NPK /ha + BF	12.47^{bc}	118.25^{c}
20: 40: 10 kg NPK /ha + BF	11.26^{bc}	109.11^{c}
Control (no fertilizers)	10.74^{c}	139.69^{b}
LSD (0.5)	1.94	15.61
SEM (±)	2.36	154.00
F-test	**	***
CV%	12.30	9.10
Grand mean	12.50	136.71

**Significant at 5% level of significance, ** significant at 1%level of significance, ***significant at 0.1% level of significance, NS: Not significant, LSD: Least significant difference, CV: Coefficient of variation*

Maximum head weight (175.85 g) and head diameter (14.87 cm) were obtained from the treatment with 80:100:60 kg NPK/ha + biofertilizer, while 60:80:40 kg NPK/ha + BF was next giving a head weight of 140.44 g and a diameter of 13.20 cm, respectively. The application of intermediate fertilizer levels (40:60:20 kg NPK/ha + BF) resulted in 118.25 g and 12.47 cm, while the lowest fertilizer levels (20:40:10 kg NPK/ha + BF) gave 109.11 g and 11.26 cm. The control (without fertilizer) produced a maximum weight of 139.69 g and the least diameter of 10.74 cm. According to Hussain *et al.* (2019), genetic variations in assimilate partitioning and sink capacity may be the cause of this variation in head weight. The higher levels of fertilizers resulted in greater head weight and diameter due to the combined effect of N, P, and K, which not only improved the head but also the disk development. These findings are consistent with the observations of Handayati and Sihombing (2019) and Nawaz *et al.* (2003).

Yield characters

Bharat 709, among the varieties gave a biological yield of 23.05 t/ha, a grain yield of 2.40 t/ha, and a harvest index of 10.71, whereas Sungold 753 reported 22.99 t /ha, 2.22 t/ha, and 9.84, respectively. The differences in yield parameters were not significant statistically for

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the different varieties. Planting under 80:100:60 kg NPK/ha + BF gave the highest grain yield (3.05 t/ha), biological yield (26.59 t/ha), and harvest index (11.58), while the next best was 60:80:40 kg NPK/ha + BF, yielding 2.67 t/ha grain, 24.69 t /ha biological, and 10.99 harvest index. The intermediate fertilizer level of 40:60:20 kg NPK/ha + BF produced 2.17 t/ha grain yield, 21.42 t/ha biological yield, and 10.44 harvest index, while the lower level of 20:40:10 kg NPK/ha + BF resulted in 1.94 t/ha grain, 20.94 t/ha biological, and 9.76 harvest index. The control with no fertilizer produced the least grain yield (1.75 t/ha), biological yield (21.28 t/ha), and harvest index (8.60).

Table 6: Effect of different varieties and levels of fertilizers with biofertilizer on yield characters of sunflower at Khairahani Chitwan during 2023

Variety	Biological yield (t/ha)	Grain yield (t/ha)	Harvest Index
Bharat 709	23.05	2.40	10.71
Sungold753	22.99	2.22	9.84
LSD (0.5)	1.62	0.66	2.88
SEM (±)	1.07	0.18	3.37
F test (0.05)	NS	NS	NS
CV%	4.50	18.10	17.80
Levels of fertilizers			
80: 100: 60 kg NPK /ha +BF	26.59^{a}	3.05^{a}	11.58^{a}
60: 80: 40 kg NPK /ha + BF	24.69^{b}	2.67^{b}	10.99^{ab}
40: 60: 20 kg NPK /ha + BF	21.42^{c}	2.17^{c}	10.44^{ab}
20: 40: 10 kg NPK /ha + BF	20.94^{c}	1.94^{cd}	9.76^{bc}
Control (no fertilizers)	21.28^{c}	1.75^{d}	8.60^{c}
LSD (0.5)	1.78	0.24	1.55
SEM (±)	2.00	0.03	1.52
F test	***	***	**
CV% b	6.20	8.20	12.0
Grand Mean	22.00	2.31	10.27

**Significant at 5% level of significance, ** significant at 1%level of significance, ***significant at 0.1% level of significance, NS: Not significant, LSD: Least significant difference, CV: Coefficient of variation*

The rise of grain and biological yields because of biofertilizer inoculation could be explained by the rising plant height, total chlorophyll content along with the yield components that are thalamus diameter, thalamus weight, number of filled seeds, capitulum characteristics, 100-seed weight, seed and stalk yield, oil content (Somasundaram *et al.*, 2010). Support for these conclusions comes from Reddy *et al.* (2015), who indicated a higher sunflower grain yield owing to the application of chemical nitrogen along with biofertilizers.

Interaction effect

For both varieties, higher levels of NPK fertilizer and biofertilizer enhanced sunflower grain production. Bharat 709 × 80:100:60 kg NPK/ha + BF (3.12 t/ha) had the maximum yield, while the control treatments had the lowest. The interaction between variety and fertilizer level was not statistically significant ($p<0.05$), showing that both varieties responded similarly to fertilizer treatment even though yield tended to rise with more fertilizer. The results of Reddy *et al.* (2015) and Kumar *et al.* (2020) are consistent with the non-significant interaction effect between variety and fertilizer levels in this study. However, higher NPK levels combined with biofertilizer increased sunflower grain yield in this study, which is in line with previous research showing that balanced fertilization improves sunflower nutrient uptake, photosynthesis, and seed filling (Khan *et al.*, 2017; Ahmad *et al.*, 2018). The

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increased nitrogen fixation, phosphorus solubilization, and increased root growth in sunflower have been linked to yield enhancement under NPK combined with biofertilizer treatment (Tilak *et al.,* 2005; Sharma & Singh, 2014).

Table 7: Effect of varieties and various levels of fertilizers with biofertilizer on interaction of grain yield.

Interaction (variety x fertilizer levels)	Grain yield (t/ha)
Bharat 709 × 80:100:60kg NPK/ha+BF	3.12
Bharat709 × 60:80:40kgNPK/ha+BF	2.81
Bharat 709 × 40:60:20kgNPK/ha +BF	2.34
Bharat 709 × 20:40:10kgNPK/ha +BF	2.05
Bharat 709 × Control (No Fertilizer)	1.67
Sungold753 × 80:100:60kgNPK/ha+BF	2.97
Sungold753× 60:80:40kgNPK/ha+BF	2.84
Sungold753 × 40:60:20kgNPK/ha+BF	2.00
Sungold753 × 20:40:10kgNPK/ha+BF	1.82
Sungold753× Control (No Fertilizer)	1.84
LSD (0.5)	0.33
F test	Ns
CV%	8.24
Grand mean	2.31

NS: Not significant, LSD (0.5): Least significant difference, CV: Coefficient of variation

CONCLUSION

The research concluded that the factors of sunflower variety, fertilizer, and bio-fertilizer are decisive for its growth and yield. The Bharat-709 variety always showed better results than the Sungold-753 variety. Moreover, the combination of NPK of 80:100:60 kg/ha with PSB and KSB gave the maximum grain yield, leaf area index, and disk weight. Most of the traits related to growth and phenology were not significant but the parameters of yield could be given a boost through integrated nutrient management. Thus, it will not only increase efficiency of the nutrient but also reduces dependency on chemicals while sustaining soil health. In essence, combining Bharat-709 with 80:100:60 kg NPK/ha + PSB + KSB is recommended for sustainable, high-yield sunflower production in Chitwan, Nepal.

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Authors' Contribution

Sagar Dhakal, Aashish Bandhu Aryal, Aakriti Poudel and Bibek Aryal conceptualized the study, designed the experiment, conducted the field trial, collected the data, performed statistical analysis, and prepared the original manuscript draft. All authors read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Conflict of Interest

The author has no relevant financial or non-financial interests to disclose.

Ethics Approval Statement

This field-based study did not involve humans or animals. Experimental activities were carried out with prior approval from relevant authorities and in accordance with environmental and biosafety guidelines.

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