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Research Article

The Effect of Commercial NPK Consortia (Ami NPK) On Wheat Productivity and Nutrient Uptake

Joshi Chinmay[1], Zala Viren[1], Pandya Amit[1], Zala Harpal[1], Zala Vibhakshi[1], Zala Prakasha[1] and Trivedi Nidhi S[2]*

[1]Ami Agri Bioscience Pvt ltd, Ahmedabad, Gujarat, India

[2]BioAgro Innovators LLP, Gandhinagar, Gujarat, India

***Corresponding Author:** Trivedi Nidhi S, BioAgro Innovators LLP, Gandhinagar, Gujarat, India.

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Abstract

This study aimed to evaluate the impact of commercial NPK consortia (Ami NPK) fertilizer on wheat growth, yield, and nutrient uptake. The experiment was conducted during growing season of 2019–2020. During the trial, a randomized complete block design with four treatments: a control with no biofertilizers, 100% recommended Nitrogen, Phosphorus and Potassium (NPK) mineral fertilizer, a combination of N- *Azotobacter* sp. (NCBI GenBank Accession no. - OM866264) P- *Bacillus* sp. (NCBI GenBank Accession no.- OM702712) K-*Pseudomonas* sp. (NCBI GenBank Accession no.- OM970251) without NPK, and the same microbial consortia with 50% NPK. The results showed that combining biofertilizers with 50% NPK (T4) resulted in the highest growth, including plant height of 115.6 cm, tiller count of 119.1, spikelets per spike average of 16.9, and 47.3 grains per spike. This treatment yielded the highest grain yield 55.7 kg/ha and straw yield 80.3 kg/ha. Moreover, T4 had the highest overall nutrient intake of nitrogen 131.54 kg/ha, phosphorus 28.43 kg/ha, and potassium 156.32 kg/ha. The results suggest that using ami NPK consortia can improve wheat yield and nutrient efficiency, providing a long term solution for increasing agricultural output.

Keywords: Microbial Consortia; Inorganic Fertilizer; Sustainable Agriculture; *Triticum aestivum L*

Abbreviations

NPK: Nitrogen, Phosphorus, Potassium; NCBI: National Centre for Biotechnology Information; NFB: Nitrogen Fixing Bacteria; PSB: Phosphorus Solubilizing Bacteria; KSB: Potassium Solubilizing Bacteria; RCBD: Randomized Complete Block Design; DAS: Days After Sowing

Introduction

Wheat (*Triticum aestivum L.*) is an essential nutrient source for over 35% of the world's population [1], providing more than 45% of calories and over 40% of protein requirements [2]. Its adaptability to a wide range of environmental conditions, as well as its ability to be used for a variety of food preparation purposes, make it a vital part of agricultural production [4]. Fertilizer treatments are critical for sustaining a good nutrient balance by supplementing nutrients lost through growing periods [3]. Appropriate nutrient management through fertilization is crucial for maximizing wheat development and yields. Chemical fertilizers are often used to increase soil levels of essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K), all of which are necessary for wheat development [5]. However, excessive use of chemical fertilizers can have serious environmental consequences, such as soil degradation, lower water holding capacity, nutrient leaching, and pollution. These difficulties necessitate the use of more sustainable farming methods [6].

Farmers generally use a large amount of chemical fertilizer to enhance wheat yields. However, this technique produces several environmental issues, including reduced water holding capacity, soil erosion, difficulty in mobilizing nutrients, and increased NO3 leaching and NH3 volatilization although all of these have a major effect on both the environment and human health [7]. Efforts to reduce chemical fertilizer use have identified natural fertilizers as viable alternatives that don't affect crop yield [8]. Biofertilizers have developed as viable alternatives to chemical fertilizers. Nitrogen-fixing bacteria (NFB), such as *Azotobacter* and *Azospirillum*, are essential for converting atmospheric nitrogen into forms that plants can absorb, reducing the need for chemical nitrogen fertilizers and increasing soil fertility [9]. Similarly, phosphorus-solubilizing bacteria (PSB) overcome phosphorus limitations by converting insoluble phosphorus molecules into plant-available forms, improving crop yields and soil health [10]. Phosphorus (P) is a key component for wheat growth, facilitating energy transfer, photosynthesis, and nutrient movement throughout the plant. However, the availability of phosphorus in soil is low due to its fixation in forms that plants cannot readily absorb [11]. Potassium is another essential nutrient for wheat, as it is needed for several physiological functions, including osmotic control, enzyme activation, and stress resistance [12]. Potassium-solubilizing bacteria (KSB), including *Bacillus* and *Aspergillus* species, absorb potassium from insoluble soil minerals and make it available to plants. This process supports proper plant growth and increases resilience to environmental challenges like drought and disease [13].

Ultimately, we aimed to determine the effect of integrating NFB, PSB, and KSB into fertilization methods, providing a complete alternative to chemical fertilizers and reducing their adverse environmental effects. These bio fertilizers improve nutrient availability and soil structure, helping to promote more sustainable wheat cultivation methods [14]. Additionally, in a study on wheat yield and economics in sandy loam soil, treatments with 75% NPK, zinc, sulphur, vermicompost, *Azotobactor*, and PSB yielded the highest grain yield, protein content, nitrogen, phosphorous, and potassium content [15]. Moreover this study highlights the effectiveness of Ami NPK consortia in wheat, specifically how these microbial agents improve nutrient management, increase crop yield, and promote sustainable agricultural methods.

Materials and Methods

Experimental site and soil preparation

The field experiment was conducted during the 2019–2020 growing season at the Ami Experimental Farm in Ahmedabad, Gujarat, with wheat (*Triticum aestivum L.*) as the experimental crop. A randomized complete block design (RCBD) with four variations was used. The treatments used three different Ami NPK consortia: *Azotobacter sp*. as a nitrogen source, *Bacillus sp*. as a phosphorus source, and *Pseudomonas sp*. as a potassium source. The experimental field was prepared by ploughing and levelling, and the initial doses of Ami NPK consortia were applied before planting. Wheat seeds were planted with a seed drill, and data on growth parameters, yield components, and soil nutrient status were collected and examined.

Treatments

The treatments included: T1 (Control) - soil without biofertilizer; T2 (100% NPK) - soil treated with 100% recommended dose of NPK mineral fertilizer; T3 Bio fertilizers (Ami NPK consortia) - *Azotobacter sp*. (N) + *Bacillus sp*. (P) +*Pseudomonas sp.* (K), T4 (Ami NPK consortia) - *Azotobacter sp.* (N). + *Bacillus sp*. (P) +*Pseudomonas sp.* (K) +50% Recommended dose NPK.

Molecular characterization

The molecular characterization of the NPK consortia was conducted using 16S rRNA sequencing, with the obtained nucleotide sequences deposited in the NCBI GenBank database. The corresponding GenBank accession numbers for the identified species are as follows: *Azotobacter sp.* (OM866264), *Bacillus sp.* (OM702712), and *Pseudomonas sp.* (OM970251).

Statistical analysis

The raw data collected from the experiment were statistically analysed using the appropriate analysis of variance (ANOVA) to assess treatment effects. The F-test was used to examine the statistical significance of variations in treatment values. When significant differences were identified, comparisons were made using the critical difference (CD) at a 5% significance level, allowing for detection of statistically significant differences across treatments.

Data collection and analysis

Data on plant growth parameters such as plant height, number of tillers, were measured at 30, 60 and 90 days after sowing (DAS), and number of spikelets per spike and grains per spike were recorded at 60 and 90 DAS. Grain and straw yields were measured at harvest in kilograms per hectare (kg/ha). Nutrient uptake was analysed by measuring the nitrogen (N), phosphorus (P), and potassium (K) content in both grain and straw, including total uptake for each nutrient. This methodology ensured accurate evaluation of the fertilization treatments on wheat growth and yield.

Result and Discussion

Plant height

The study conducted on wheat growth varied among the different treatments at 30, 60, and 90 days depicted in figure 1. On the 30th day of treatment, T4 indicated the highest growth compared to the other three treatments. Treatment T4 (Ami NPK consortia), which had *Azotobacter sp.* (N), *Bacillus sp.* (P), *Pseudomonas sp.* (K), and, 50% of the recommended NPK fertilizer, was more effective in improving wheat growth. With measurements of 88.9 cm and 115.6 cm, respectively. In comparison, treatment T2, which received 100% of the provided NPK mineral fertilizer, grew the second highest after T4. According to the results, adding microbial consortia to T4 (Ami NPK) improves the efficacy of NPK fertilizer when combined with microbial inoculants. In another research, wheat treated with mineral fertilizer according to fertilization recommendation and biofertlizer showed the highest plant height among other treatments. The plant reached 85.57cm of height and it was considerably greater than the control group [16]. As per other studies, the highest plant height of 102.34 cm was obtained with the T5 treatment, which included half of the recommended dose of NPK fertilizer, biofertilizers (biozote), and boron [17].

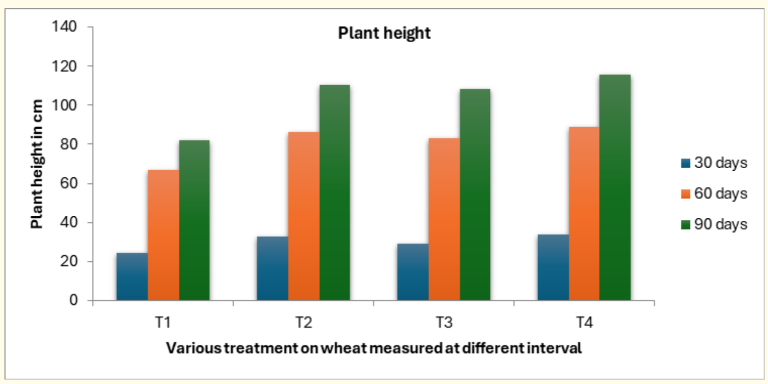

Figure 1: Effect of various biofertilizer treatments on plant height.
Where, T1 control (soil without biofertilizer), T2- 100% NPK mineral fertilizer, T3- *Azotobacter* sp (n)+ *Bacillus* sp. (p) + *Pseudomonas* sp. (k), T4- *Azotobacter* sp. (n) + *Bacillus* sp. (p) + *Pseudomonas* sp.(k)+ 50% NPK.

Number of tillers

Tiller growth in wheat was examined at 60 and 90 days after planting under four different treatment applications. Figure 2 showed that Treatment T4 had the maximum development with 138.4 tillers at 60 days, surpassing the tiller counts in the other three treatments. The same result occurred during the 90 days, with Treatment T4 consistently exhibiting a larger tiller count of 119.1 compared to treatments T1, T2, and T3. Notably, the control group (T1) recorded 98.07 tillers at 60 days and 110.1 tillers at 90 days, both profoundly lower than the counts observed in treatment T4. Another investigation suggests that the application of *Azotobacter* and PSB alone resulted in 93.51 number of tillers (per meter row length), compared to 79.79 plants per meter in the control group without inoculation [18]. Also, our result was in close agreement with an additional study on wheat. By applying the MPKV consortia (a combination of PSB and KMB) with 100% RDF, they got 10.8 tillers per hill, the highest among other treatments [19].

Number of spikelets spike

Figure 3 shows the impact of different treatments on the number of spikelets per spike in wheat crops, with notable results. The control (T1) produced the fewest spikelets. Treatment T2, which included the application of 100% NPK mineral fertilizer, greatly increased this number, yielding an average of 15 spikelets per spike. Treatment T3 (Ami NPK consortia), which included a mixture of *Azotobacter sp.* (N-fixing), *Bacillus sp.* (P-solubilizing), and *Pseudomonas sp.* (K-solubilizing), produced 13 spikelets per spike. The most pivotal improvement was observed in treatment T4, where the biofertilizers combination (Ami NPK consortia) was added with 50% NPK fertilizer, produced the highest with 16.9 spikelets per spike. In an additional study, the application of FYM and the recommended dose of NPK produced 13.90 spikelets per spike. In contrast, the untreated control group exhibited the lowest spikelet rate, with only 10.80 spikelets per spike [20]. Although previous research obtained a yield of 23.03 using a mixture of organic fertil-

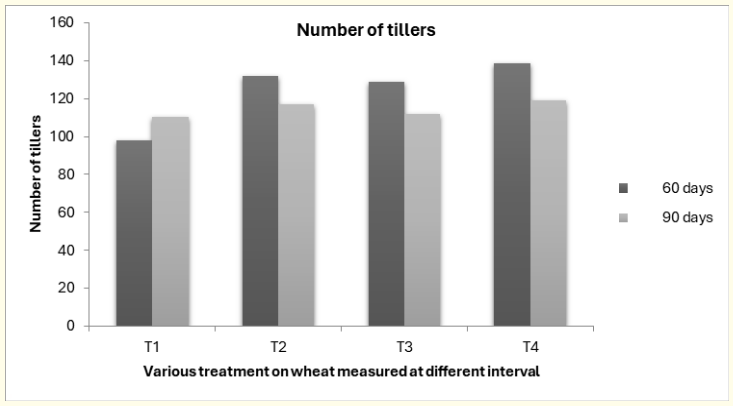

Figure 2: Effect of various biofertilizer treatment on number of tillers.
Where, T1 control (soil without biofertilizer), T2- 100% NPK mineral fertilizer, T3- *Azotobacter* sp (n)+ *Bacillus* sp. (p) + *Pseudomonas* sp. (k), T4- *Azotobacter* sp. (n) + *Bacillus* sp. (p) + *Pseudomonas* sp.(k)+ 50% NPK.

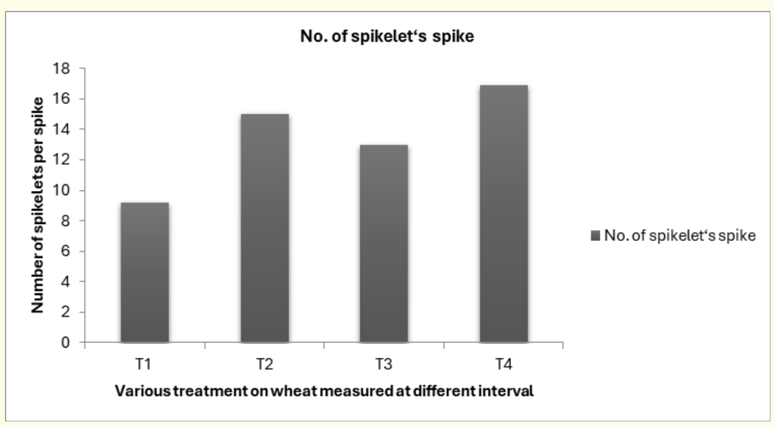

Figure 3: Effect of various biofertilizer treatments on Number of spikelet's spike.
Where, T1 control (soil without biofertilizer), T2- 100% NPK mineral fertilizer, T3- *Azotobacter* sp (n)+ *Bacillus* sp. (p) + *Pseudomonas* sp. (k), T4- *Azotobacter* sp. (n) + *Bacillus* sp. (p) + *Pseudomonas* sp.(k)+ 50% NPK.

izer and 50% nitrogen (37.5 kg), our results were similarly valuable under the given experimental conditions. This indicates that our technique was also effective in producing optimal yields [21].

Number of grain per spike

The results of the experiment showed (figure 4) a considerable variation in the number of grains per spike between treatments. The control group (T1) had the fewest grains per spike, averaging 27.5. Treatment T2 developed a considerable rise, with an average of 47 grains per spike. Treatment T3 also exhibited a notable increase in grain yield, with an average of 44 grains per spike, demonstrating its efficacy. Treatment T4 had the greatest grain count, measuring 47.3 grains per spike, although the difference between T2 and T4 in grains per spike was minimal, T4 slightly outperformed other treatments. Overall, the experimental treatments T2, T3, and T4 all improved grain yield compared to the control, with T4 being the most effective. However, our observations on wheat crops are consistent with a previously reported study that used nitrogen-fixing bacteria (7.5 kg/ha as PSB), which produce 45.57 grains per spike [22]. These results correspond with earlier studies, where research found that applying *Enterobacter spp.* Strains + 120 kg/ha N+ P_2O_5 and K_2O produce 9.43 ± 0.04 t/ha wheat grains. It proves that NPK alone is less effective in increasing wheat grain production [23].

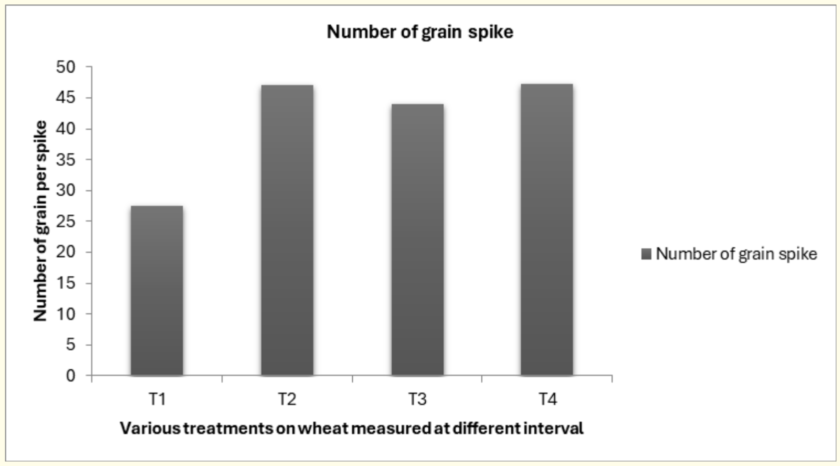

Figure 4: Effect of various biofertilizer treatments on the number of grains per Spike in wheat.
Where, T1 control (soil without biofertilizer), T2- 100% NPK mineral fertilizer, T3- *Azotobacter* sp (n)+ *Bacillus* sp. (p) + *Pseudomonas* sp. (k), T4- *Azotobacter* sp. (n) + *Bacillus* sp. (p) + *Pseudomonas* sp.(k)+ 50% NPK.

Grain and straw yield

The above table 1 evaluates various treatment impacts on grain and straw yields. The control treatment (T1), which used soil without bio fertilizer, produced 39.4 kg/ha of grain and 52.11 kg/ha of straw. Using 100% NPK mineral fertilizer (T2) enhanced yields by 48.9 kg/ha and 77.8 kg/ha, respectively. Treatment T3, that contained an Ami NPK consortia of bio fertilizers (*Azotobacter sp.* (n), *Bacillus sp.* (p), and *Pseudomonas sp.* (k), produced a comparable yield of 48.7 kg/ha for grain and 77.1 kg/ha for straw. Notably, the combined usage of these bio fertilizers and 50% NPK (T4) resulted in the highest yields of 55.7 kg/ha for grain and 80.3 kg/ha for straw. These result are comparable with a prior study in which 50% urea and 50% farm manure used, resulted in a grain yield of 4.11 mg/ha and a straw yield of 7.14 mg/ha. This treatment found to be more effective than other treatments tried in the experiment [24]. The results of the current study align with those of previous investigators, who utilized a mixture of 100% NPK, farmyard manure (FYM), sulphur, *Azotobacter*, and PSB. Their research reported a grain yield of 50.54 q/ha and a straw yield of 81.60 q/ha. These results correspond with the findings of our study, which showed a similar yield increase under comparable treatment [25].

Table 1: Effect of Different Dosages of NPK Consortia on Grain and Straw Yields (kg/ha) in Wheat Cultivation.

Treatments	Grain Yield kg/ha	Straw yield kg/ha
T1 control (soil without biofertilizer)	39.4	52.11
T2- 100% NPK mineral fertilizer	48.9	77.8
T3- *Azotobacter sp* (n)+ *Bacillus sp* (p)+ *Pseudomonas sp* (k)	48.7	77.1
T4- *Azotobacter sp* (n)+ *Bacillus sp* (p)+ *Pseudomonas sp* (k)+ 50% NPK	55.7	80.3

Total nitrogen uptake

Nitrogen uptake was measured in grain and straw through four treatments T1–T4 (table 2). The control (T1) resulted in a nitrogen intake of 41.2 kg/ha in grain and 12.98 kg/ha in straw, leading to a total nitrogen uptake of 51.9 kg/ha by wheat. Treatment 2 (T2) increased nitrogen intake considerably, with 78.12 kg/ha in grain and 37.56 kg/ha in straw, with a total nitrogen uptake of 119.67 kg/ha by wheat. Similarly, T3 had a nitrogen intake of 75.28 kg/ha in grain and 33.11 kg/ha in straw, resulting in 113.1 kg/ha overall by wheat. T4 had the maximum nitrogen uptake (89.2 kg/ha in grain and 44.5 kg/ha in straw), totaling 131.54 kg/ha. These findings show that the treatments varied in nitrogen absorption efficiency, with T4 having the highest total nitrogen uptake. A comparable result was reported in another investigation in which nitrogen was used as the nutrient source. According to the study, wheat absorbs 87.3 kg/ha of grain nitrogen, 35.3 kg/ha of straw nitrogen, and 109.8 kg/ha of total nitrogen. These values were higher than

Table 2: Total nitrogen uptakein wheat from straw and grain under different fertility treatments.

Treatments	N-Uptake (kg/ ha)		Total N Uptake kg/ha
	Grain	Straw	
T_1	41.2	12.98	51.9
T_2	78.12	37.56	119.67
T_3	75.28	33.11	113.1
T_4	89.2	44.5	131.54

the control, confirming the importance of nitrogen as an essential element in increasing overall nitrogen uptake in wheat [26]. Further research was reported by using potassium and *Azotobacter spp*. In another research, and they get 2.89% N and 0.86% N grain and straw yield of total nitrogen uptake [27].

Total phosphorus uptake

The table 3 represents the phosphorus (P) uptake by wheat crops in different treatments, including grain and straw. In Treatment T1, the wheat crop absorbed 3.4 kg/ha of grain P and 3.1 kg/ha of straw P, yielding 5.9 kg/ha total. T2 improved grain and straw P intake to 14.12 kg/ha and 10.12 kg/ha, respectively, resulting in a total P uptake of 26.5 kg/ha. In Treatment T3, grain P uptake was 13.78 kg/ha, while straw uptake was 11.34 kg/ha, totaling 25.45 kg/ha. Treatment T4 had the maximum P uptake of 16.2 kg/ha of grain and 12.45 kg/ha of straw, with the wheat crop absorbing a total intake of 28.43 kg/ha. Another study found that using 100% of the recommended NPK fertilizers resulted in a grain yield of 26 q/ha and a straw production of 39.5 q/ha. The overall phosphorus utilization efficiency in wheat grain was reached to 19.5% [28].

Table 3: Total phosphorus uptake in wheat from straw and grain under different fertility treatments.

Treatments	P-Uptake kg/ha		Total
	Grain	Straw	P-Uptake kg/ha
T_1	3.4	3.1	5.9
T_2	14.12	10.12	26.5
T_3	13.78	11.34	25.45
T_4	16.2	12.45	28.43

Total Potassium uptake

Potassium uptake was evaluated for each treatment, with results indicating variations in both grain and straw components as depicted in table 4. Treatment T1 had 13.21 kg/ha of potassium uptake in grain and 36.9 kg/ha in straw. Treatment T2 had 38.56 kg/ha of potassium uptake in grain and 33.42 kg/ha in straw. Treatment T3 had a grain potassium absorption of 35.23 kg/ha, and straw contributed 32.14 kg/ha. Treatment T4 resulted in 36.23 kg/ha of potassium absorption in grain and 113 kg/ha in straw. The total potassium uptake for each treatment demonstrates significant nutrient buildup variations. Treatment T1 resulted in a total potassium intake of 55.32 kg/ha. Treatment T2 had the highest overall uptake at 156.34 kg/ha. Treatments T3 and T4 have a total consumption of 152.31 kg/ha and 156.32 kg/ha, respectively. These results demonstrate the varied efficiency of potassium use among treatments, with treatments T2 and T4 exhibiting the highest overall nutrient absorption. A related study on soybeans crop yields found a similar pattern, with a grain yield of 30.65 kg/fed after applying 75% NPK + mycorrhizal fungi+ potassium humate [29]. A similar study on wheat with basal of *Azotobacter* + PSB produced 0.538% grain yield and 1.466% straw yield with regard to potassium uptake [30].

Table 4: Total Potassium uptake in wheat from straw and grain under different fertility treatments.

Treatments	K-Uptake kg/ha		Total
	Grain	Straw	K-Uptake kg/ha
T_1	13.21	36.9	55.32
T_2	38.56	33.42	156.34
T_3	35.23	32.14	152.31
T_4	36.23	113	156.32

Conclusion

The present study evaluates the impact of Ami NPK consortia on enhancing wheat yields. The use of bio fertilizers in combination with reduced doses of mineral NPK fertilizers, can improve plant growth parameters like crop height, tiller count, and spikelet development. Also, grain and straw yields were developed in higher amounts after using the Ami NPK consortia. In addition, incorporating Ami NPK bio fertilizers can increase nutrient uptake and crop productivity, encouraging sustainable agriculture by improving soil health and long-term viability. These advantages indicate ability of Ami NPK consortia to improve wheat productivity and reduce chemical fertilizer usage.

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