RESEARCH ARTICLE

Exploring the impacts of varied natural and organic farming approaches on growth attributes and yield of wheat (*Triticum aestivum* L.) based intercropping systems in the sub humid climatic conditions of Himachal Pradesh

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Raveena, Kumar R, Shilpa. Exploring the impacts of varied natural and organic farming approaches on growth attributes and yield of wheat (*Triticum aestivum* L.) based intercropping systems in the sub humid climatic conditions of Himachal Pradesh. AGBIR.2024;40(1):827-833.

A field experiment was conducted during rabi 2021 at the Zero Budget Natural Farm (ZBNF), Department of Organic Agriculture and Natural Farming, COA, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, to compare the effect of natural and organic farming techniques on the growth and yield of wheat. The study employed a randomized block design with thirteen treatments replicated three times. The results showed that the treatment comprised of wheat+gram and jeevamrit spray at 14 days' interval led to significantly greater growth attributes, viz., plant height at 90, 120, 150 DAS and at harvest (32.3, 63.5, 89.7 and 92.1 cm) and number of tillers per square meter at 90, 120, 150 DAS and at harvest (193.7, 232.4, 222.1 and 214.5) of wheat. Similarly, the treatment wheat sole and jeevamrit spray at 14 days' interval resulted in significantly higher grain and straw yields (16.07 q/ha and 30.53 q/ha). The highest wheat equivalent yield (18.37 q/ha) was achieved using organic farming practices wheat+gram and matka khad spray at 30 days' interval followed by wheat+lentil and matka khad spray at 30 days' interval (17.07 q/ha). Therefore, it was concluded that treatment comprised of organic package of practices along with the application of matka khad at 30 days' interval was found to be the best treatment with respect to crop growth and productivity of main crop as well as intercrops. In conclusion, the most effective treatment for crop growth and productivity, both for the main crop and intercrops, was found to be the organic approach with matka khad application at 30-day intervals.

Key Words: *Growth; Jeevamrit; Matka khad; Natural farming; Organic farming; Yield*

INTRODUCTION

Over the past 50 years, significant increases in wheat yield have been realized through changes in agricultural practices. These changes include the widespread use of synthetic fertilizers and pesticides, as well as the development of crop varieties adapted to these conditions. Notably, the introduction of dwarfing genes has played a pivotal role in enhancing wheat yield by improving the harvest index [1]. However, in recent years, it has become increasingly apparent that a yield plateau has been reached for many crops [2]. This plateau means that the traditional methods of boosting crop yields are no longer as effective, and we need to find new approaches to maintain and increase yields sustainably. This is a pressing concern, given the world's growing population, which is expected to reach 9 billion people by 2050. As the population expands, there will be competing demands for land, including its use for energy production. Therefore, it's imperative to find ways to meet the world's food needs while preserving the environment and ensuring the sustainability of agricultural practices.

Traditional farming heavily depends on using various modern management methods and external resources to achieve high crop yields [3]. Unfortunately, a consequence of this approach has been the development of resistance to pesticides in recent years [4-6]. Additionally, the intensive use of pesticides and synthetic fertilizers has led to environmental problems [7]. Some pests have become resistant to control methods like resistance genes and pesticides faster than new solutions can be developed [8], particularly in the case of wheat. This growing pest issue is happening at a time when important pesticides are being phased out and resistance genes are weakening because of extensive farming and climate change [9]. Furthermore, changes in the EU Pesticide Directive (91/414/EEC) are expected to have significant effects on crop production in member states. These changes will require the removal of roughly 20% of active ingredients in the near future [10]. This means that more food will need to be produced using fewer pesticides.

Ensuring continuous crop productivity on arable land for future generations while preserving the environment is a critical challenge. Organic farming aims to avoid the regular use of synthetic fertilizers, pesticides, and growth regulators [11,12]. To achieve this, it relies on practices such as crop rotation, cultivation methods, appropriate sowing schedules, and the use of resistant crop varieties. Low-input and organic farming systems typically result in lower and more variable crop yields. This is because they involve longer crop rotations and reduced use of fertilizers and pesticides [13].

Compared to conventionally managed farms, organic farms have richer and more diverse populations of helpful organisms in their soils. Organic farming results in a 20-30% increase in microbial biomass and a 30-100% boost in microbial activity [14]. However, it's important to recognize that organic farming demands substantial inputs like farmyard manure, green manure, compost, and vermin-compost to provide the necessary nutrients for crops. This can be a challenge for small and marginal farmers, particularly those with limited livestock. They often have to purchase bulky organic fertilizers from outside sources, incurring additional transportation costs on top of their cultivation expenses. In such cases, this practice can become financially unsustainable for them. To address this issue, "Padma Shree Subhash Palekar" introduced an innovative concept called "Zero Budget Natural Farming (ZBNF)." ZBNF is a farming approach that requires minimal external inputs and doesn't rely on credit. It makes use of locally available resources and effectively reduces production costs while increasing crop yields. This approach aims to make farming financially viable for small and marginal farmers, allowing them to grow crops sustainably without the burden of excessive expenses. Zero Budget Natural Farming (ZBNF) comprises four fundamental components: Beejamrit: This involves coating seeds with a mixture of cow dung and urine. It's a natural way to enhance seed quality

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Received: 05-Dec-2023, Manuscript No. AGBIR-23-122059; **Editor assigned:** 07-Dec-2023, Pre QC No. AGBIR-23-122059 (PQ); **Reviewed:** 25-Dec-2023, QC No. AGBIR-23-122059; **Revised:** 03-Jan-2024, Manuscript No. AGBIR-23-122059 (R); **Published:** 11-Jan-2024, DOI:10.35248/0970-1907.24.40.827-833

and promote healthy plant growth. Jeevamrit: This method enriches the soil and increases its vitality. It's like giving the soil a boost of energy to help crops thrive. Acchadana: This practice involves using mulch to cover the soil, preserving moisture, and protecting the soil from harsh environmental conditions. Whapasa: It's all about maintaining the right soil moisture levels, ensuring that the soil is neither too dry nor too wet for optimal plant growth. In ZBNF, intercropping with legumes plays a crucial role in maintaining soil fertility while achieving good crop yields. This is particularly important in a country like India, where cases of Protein Energy Malnutrition (PEM) are high, and there's a need for increased pulse production to ensure the nutritional security of vulnerable members of society. The core idea of natural farming is to encourage the growth of beneficial microbes without relying on external fertilizers or synthetic pesticides. Legumes, in this context, are valuable because they capture atmospheric nitrogen, enriching the soil [15]. Some states in India, like Himachal Pradesh and Uttarakhand, have already embraced natural farming, mainly due to their challenging terrain, which limits access to traditional farming inputs. Since agriculture is the primary source of livelihood for small and marginal farmers in Himachal Pradesh, there's a compelling need to promote and advance research and extension activities in the field of natural farming. With all these considerations in mind, this study was conducted to evaluate the impact of natural and organic farming techniques on the productivity of intercropped wheat and legume systems. The goal is to understand how these methods can help boost crop yields and improve soil health, addressing both food security and sustainability concerns.

Sustainable arable crop production can be achieved by identifying the key areas of production in terms of nutrient management and crop protection to achieve long-term sustainable yields. Hence, keeping in view the above-mentioned points, aim of this study was to determine the effect of different natural and organic farming techniques on the productivity of wheat+legume intercropping systems.

MATERIALS AND METHODS

The research was conducted at the Zero Budget Natural Farm (ZBNF) in the Department of Organic Agriculture & Natural Farming, COA, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, during the winter cropping season of 2020-21. This farm is located at 32°09'N latitude, 76°05'E longitude, at an elevation of 1224 meters above sea level in Palampur, Kangra district of Himachal Pradesh. The study involved intercropping wheat with gram and lentils. Specifically, we used the recommended wheat variety, HPW 368, with a planting spacing of 22.5 × 5 cm. For gram, we used the Himachal chana-I variety, and for lentils, the Vipasha variety was selected, with a recommended spacing of 30 × 15 cm for timely sowing in the mid-hills region. Before planting the wheat, we applied ghanjeevamrit in the natural farming plots, while in the organic farming plots, we used Farm Yard Manure (FYM) during the final field preparation. Additionally, we treated the seeds with beejamrit and biofertilizers following specific treatment protocols for each. In the natural farming plots, we applied jeevamrit through spraying at intervals of 14, 21, and 28 days, while in the organic farming plots, we used matka khad at 30-day intervals. Standard procedures were followed for nutrient analysis of various traditional inputs. Notably, the highest levels of Nitrogen (N), Phosphorus (P) and Potassium (K) were found in ghanjeevamrit, with respective percentages of 1.25, 0.87 and 0.68. This was followed by beejamrit with percentages of 0.72, 0.14 and 0.23 and jeevamrit with percentages of 0.25, 0.13 and 0.15, respectively. Preparation methodology and application procedures of different inputs used in experiment given in Table 1.

TABLE 1

Preparation methodology and application procedures of different inputs used in experiment

Input	Ingredients	Preparation methodology	Application methodology
Beejamrit	Cow dung-5 kg Cow urine-5 l Lime-50 g Water-20 l Fertile soil-500 gm	Cow urine, cow dung and lime, all mixed in a 20 l PVC drum filled with water and left overnight.	Sprinkled on the seed, mixed with hand and dried in the shade for 30 minutes before sowing.
Ghanjeevamrit	Cow urine-5 l Cow dung-100 kg Besan-1-2 kg Jaggery-1 kg Fertile soil-500 gm	Took cow dung, cow urine, jaggery, pulse flour (gram) and soil from the bund of the field. All were thoroughly mixed and the heap was prepared in the shade, covered with jute bags and balls were made with hand and kept in the shade.	Broadcasted @ 500 kg/ha before sowing uniformly in each plot except control (T_{13}) and organic plots.
Jeevamrit	Cow urine-10 l Cow dung-10 kg Besan-2 kg Jaggery-2 kg Water-200 l Fertile soil-500 gm	Cow dung, cow urine, jaggery, pulse flour (gram) and virgin soil from the bund of the field, all were mixed in 200 l water in a PVC drum. This solution was kept for three days in the shade and stirred twice daily for one minute with a wooden stick.	Applied through foliar spray as per treatment requirement.
Matka khad	Cow dung-5 kg Cow urine-5 l Jaggery-250 g Water-5 l	The necessary ingredients were carefully mixed before being poured into a pitcher. kept the pitcher buried in the ground and the lid was placed over the mouth of the pitcher. After 8-10 days, it was ready for use.	Applied through foliar spray as per treatment requirement.

Statistical analysis

Data was analyzed using Analysis of Variance (ANOVA) in accordance with the protocol provided by Gomez and Gomez in order to determine whether significant differences were the outcome of the randomized block design [16]. At the 5% level of probability, conclusions were formed. A calculation of the standard error of mean was applied to every example. A minimal significant difference was computed in cases when the analysis of variance tables 'F' value indicated significance.

Observations recorded

Emergence count/m2 at 15 days after sowing; the total number of plants present in the net plot were counted after sowing. Plant height: Five plants of wheat were selected at random from the net plot area of each plot and were tagged. The height was measured at 30 days' interval and at harvest of crop and mean height was calculated by dividing the total plant height of five plants by five. Number of tillers per square meter; number of tillers per meter row length were counted at 30 days' intervals from the net plot area and then number of tillers per square meter was calculated. Grain yield; after threshing of crops, net plot seed yield was weighted and recorded for each plot individually and expressed as grain yield (q/ha). Similarly grain equivalent yield; was calculated according to the standard procedure [17].

RESULTS AND DISCUSSION

Growth attributes

Different treatments did not have significant effect on the emergence count per square meter of wheat (Table 2). While the plant height of wheat at 60, 90, 120, 150 DAS and at harvest was significantly influenced by the natural and organic farming practices from 90 days after sowing till harvest during. Significantly taller plants of wheat (32.3 cm, 63.5 cm, 89.7 cm and 92.1 cm) at 90, 120, 150 DAS and at harvest were recorded with the treatment wheat+gram and jeevamrit spray at 14 days' interval (T_1) and it remained statistically at par with the treatments T_4, T_2 and T_5 (Table 2).

TABLE 2

Effect of treatments on emergence count and plant height of wheat crop

Treatments	Emergence count/m²	Plant height (cm)				
		60 DAS	90 DAS	120 DAS	150 DAS	At harvest
	2020-21	2020-21	2020-21	2020-21	2020-21	2020-21
T_1-Wheat+gram and jeevamrit spray at 14 days interval	92.26	12.7	32.3	63.5	89.7	92.1
T_2-Wheat+gram and jeevamrit spray at 21 days interval	91.52	12.5	30.5	58.9	85.8	86.7
T_3-Wheat+gram and jeevamrit spray at 28 days interval	90.15	11.7	26.7	49.1	77.9	78.6
T_4-Wheat+lentil and jeevamrit spray at 14 days interval	91.66	13.2	31.4	61.4	87.6	90.8
T_5-Wheat+lentil and jeevamrit spray at 21 days interval	91.45	12.5	29.8	59.5	84.5	87.7
T_6-Wheat+lentil and jeevamrit spray at 28 days interval	91.32	11.8	25.5	48.2	78.1	77.5
T_7-Wheat (sole) and jeevamrit spray at 14 days interval	91.18	12.6	27.7	52.6	79.4	80.5
T_8-Wheat (sole) and jeevamrit spray at 21 days interval	90.33	12.7	24.6	48.4	74.3	73.5
T_9-Wheat (sole) and jeevamrit spray at 28 days interval	90.53	12.4	23.8	45.9	71.4	71.6
T_{10}-Wheat+gram (Organic package of practices)	91.18	12.5	28.3	54.3	81.2	82.3
T_{11}-Wheat+lentil (Organic package of practices)	90.94	12.6	27.9	53.6	80.1	80.4
T_{12}-Wheat sole (Organic package of practices)	91.20	12.4	25.6	46.5	72.6	75.7
T_{13}-Wheat sole (Absolute control)	90.60	11.1	22.5	43.3	68.5	69.3
SEm ±	1.98	0.4	0.8	1.6	2.1	2.2
LSD (P=0.05)	NS	NS	2.5	4.7	6.2	6.5

Note: DAS=Days After Sowing.

In natural farming plots, the application of jeevamrit (14 days' interval) along with mulching resulted in adequate moisture availability in the root zone. This also promoted the solubilization of nutrients by beneficial soil microbes resulting in improved utilization of plant nutrients by wheat plants. Additionally, mulching played a role in moisture retention and weed control in the soil [18]. Notably, the lowest plant height measurements were consistently observed under the absolute control treatment (T_{13}) across the season. From the data, it was inferred that there was an increase in number of tillers per square meter up to 120 DAS and thereafter, it decreased gradually (Table 3). This is due to the mortality of shoots, as a result of intra plant competition for light, space and nutrition. Different treatments significantly influenced the number of tillers per square meter at all the stages of observations except at 60 DAS during both the seasons. Significantly higher number of tillers (193.7, 232.4, 222.1 and 214.5) were produced at 60, 90, 120, 150 DAS and at harvest, respectively under T_1 (wheat+gram and jeevamrit spray at 14 days' interval) which was found to be statistically at par with T_4 and T_7. Absolute control produced the lesser number of tillers followed by treatment where sole planting of wheat was done along with application of jeevamrit at 28 days' interval (T_9). The reduced number of tillers per square meter in sole planting of wheat, compared to an intercropping system where one row of wheat was replaced by an intercrop such as gram or lentil, can be attributed to both inter and intra plant competition for resources. This competition negatively affected tiller development per plant in the sole planting system. In contrast, intercropping exhibits a complementary effect with nutritive transfer and reduced competition due to the distinct growth habits of the main crop and intercrop. These factors contributed to the maximum number of tillers per plant observed in the intercropping system [19].

In case of number of days taken to maximum tillering, 50% flowering and physiological maturity presented in Table 4, different treatments under natural and organic farming practices had no significant influence.

TABLE 3

Effect of treatments on number of tillers of wheat crop

Treatments	Number of tillers/m^2				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
	2020-21	2020-21	2020-21	2020-21	2020-21
T_1-Wheat+gram and jeevamrit spray at 14 days interval	164.1	193.7	232.4	222.1	214.5
T_2-Wheat+gram and jeevamrit spray at 21 days interval	162.3	178.2	213.8	207.4	200.3
T_3-Wheat+gram and jeevamrit spray at 28 days interval	162.1	178.5	214.2	208.8	201.2
T_4-Wheat+lentil and jeevamrit spray at 14 days interval	165.2	191.4	229.7	218.5	208.6
T_5-Wheat+lentil and jeevamrit spray at 21 days interval	163.7	180.1	216.1	209.3	203.3
T_6-Wheat+lentil and jeevamrit spray at 28 days interval	163.5	179.8	215.8	207.6	200.4
T_7-Wheat (sole) and jeevamrit spray at 14 days interval	164.2	187.2	224.7	216.9	211.4
T_8-Wheat (sole) and jeevamrit spray at 21 days interval	159.9	175.9	211.2	204.7	198.6
T_9-Wheat (sole) and jeevamrit spray at 28 days interval	160.2	176.3	210.8	205.2	198.7
T_{10}-Wheat+gram (Organic package of practices)	164.1	180.5	216.6	210.1	199.6
T_{11}-Wheat+lentil (Organic package of practices)	163.7	180.1	216.1	209.3	202.3
T_{12}-Wheat sole (Organic package of practices)	164.2	180.6	214.4	210.2	199.7
T_{13}-Wheat sole (Absolute control)	153.5	165.7	198.9	192.6	183.3
SEm ±	4.0	2.9	3.7	3.8	3.4
LSD (P=0.05)	NS	8.6	10.7	11.1	9.8

Note: DAS=Days After Sowing.

TABLE 4
Effect of treatments on developmental stages of wheat crop

Treatments	Days taken to maximum tillering stage	Days taken to 50% flowering stage	Days taken to physiological maturity
T_1-Wheat+gram and jeevamrit spray at 14 days interval	124.8	126.7	178.9
T_2-Wheat+gram and jeevamrit spray at 21 days interval	125.3	127.3	179.4
T_3-Wheat+gram and jeevamrit spray at 28 days interval	126.8	128.1	182.3
T_4-Wheat+lentil and jeevamrit spray at 14 days interval	124.7	126.3	178.6
T_5-Wheat+lentil and jeevamrit spray at 21 days interval	125.7	127.3	179.7
T_6-Wheat+lentil and jeevamrit spray at 28 days interval	126.6	127.9	181.3
T_7-Wheat (sole) and jeevamrit spray at 14 days interval	126.4	127.8	182.3
T_8-Wheat (sole) and jeevamrit spray at 21 days interval	127.7	128.3	183.9
T_9-Wheat (sole) and jeevamrit spray at 28 days interval	127.9	128.2	183.8
T_{10}-Wheat+gram (Organic package of practices)	125.8	127.7	178.7
T_{11}-Wheat+lentil (Organic package of practices)	125.3	127.3	178.8
T_{12}-Wheat sole (Organic package of practices)	126.3	128.6	183.8
T_{13}-Wheat sole (Absolute control)	127.7	129.2	184.6
SEm±	1.14	1.91	2.50
LSD (P=0.05)	NS	NS	NS

Yield

Wheat sole and jeevamrit spray at 14 days' interval (T_7) recorded significantly higher grain yield (16.07 q/ha) of wheat followed by T_8 (wheat sole and jeevamrit spray at 21 days' interval) and it was statistically at par with T_9 (wheat sole and jeevamrit spray at 28 days' interval) and T_{12} (wheat sole and matka khad spray at 30 days' interval) (Table 5). Higher grain yield can be attributed to more number of rows in sole planting of wheat as compared to intercropping system (replacement series), where number of rows were less which directly influenced the number of effective tillers per hectare and yield of wheat [20]. However, among the intercropping treatments, T_{11} (wheat+lentil and matka khad spray at 30 days' interval) resulted in higher grain yield, which remained statistically at par with the T_4, T_{10}, T_1 and T_5. Jeevamrit, characterized by a significant microbial load, exhibited the ability to proliferate within the soil, acting as a tonic to enhance soil microbial activity. This process sustained the availability and uptake of both applied as well as indigenous soil nutrients, ultimately leading to improved crop growth and yield [18,21]. Lower grain yield (9.52 q/ha) was recorded under absolute control which was due to the inability of the soil to provide adequate amount of nutrients to the plants in the absence of any external source of nutrients.

Wheat grain equivalent yield was significantly higher (18.37 q/ha) under organic farming practices T_{10} (wheat+gram and matka khad spray at 30 days' interval) followed by T_{11} (wheat+lentil and matka khad spray at 30 days' interval) (17.07 q/ha). The higher yield and economic value observed in the intercropping treatments may be attributed to the additional advantage of intercrops (Table 5). Treatments where jeevamrit was applied at 28 days' interval (T_3, T_6 and T_9) exhibited a significant reduction in wheat grain equivalent yield compared to other intercropping treatments. This decrease in wheat equivalent yield could be attributed to the lower yields of both the main crop and intercrop, as compared to other intercropping treatments [22,23].

As compared to sole treatments, the increment in the wheat grain equivalent yield of T_{10} was 14.31%, 24.54%, 25.91%, and 27.57% over T_7, T_8, T_9, and T_{12}, respectively. The data pertaining to the effect of different treatments on the straw yield followed the same trend as that of the grain yield. The treatment T_7 had significantly higher straw yield (30.53 q/ha) of wheat followed by T_8, which remained statistically at par with the T_9 and T_{12}. The higher plant population under sole planting of wheat resulted in an increased number of tillers, thereby leading to a higher yield of straw [20,24].

Intercrops studies

Yield (Gram and lentil): Perusal of data in Figures 1 and 2 indicated that seed yield (2.51 and 2.15 q/ha) and straw yield (3.69 and 3.04 q/ha) of gram and lentil was highest under organic treatment wheat+lentil and matka khad spray at 30 days' interval followed by natural farming treatment wheat+gram/lentil and jeevamrit spray at 14 days' interval. The higher yield obtained in organic farming treatments might be attributed to the application of FYM, which increased the organic matter content of the soil which in turn, improved the soil structure, water-holding capacity, and nutrient availability for more root growth and better nutrient uptake, as demonstrated in several studies [25,26].

TABLE 5
Effect of treatments on yields of different crops and wheat equivalent yield

Treatments	Grain/seed yield (q/ha)			WEY (q/ha)	Straw yield
	Wheat	Gram	Lentil		
T_1-Wheat+gram and jeevamrit spray at 14 days interval	13.07	1.48	-	16.92	24.82
T_2-Wheat+gram and jeevamrit spray at 21 days interval	11.99	1.51	-	15.92	22.77
T_3-Wheat+gram and jeevamrit spray at 28 days interval	12.25	1.29	-	15.60	23.27
T_4-Wheat+lentil and jeevamrit spray at 14 days interval	12.88	-	1.40	16.35	24.47
T_5-Wheat+lentil and jeevamrit spray at 21 days interval	12.11	-	1.77	16.50	23.04
T_6-Wheat+lentil and jeevamrit spray at 28 days interval	12.69	-	1.70	16.91	24.11
T_7-Wheat (sole) and jeevamrit spray at 14 days interval	16.07	-	-	16.07	30.53
T_8-Wheat (sole) and jeevamrit spray at 21 days interval	14.75	-	-	14.75	28.02
T_9-Wheat (sole) and jeevamrit spray at 28 days interval	14.59	-	-	14.59	27.72
T_{10}-Wheat+gram (Organic package of practices)	11.84	2.51	-	18.37	22.49
T_{11}-Wheat+lentil (Organic package of practices)	11.74	-	2.15	17.07	22.30
T_{12}-Wheat sole (Organic package of practices)	14.40	-	-	14.40	27.35
T_{13}-Wheat sole (Absolute control)	9.52	-	-	9.52	18.08
SEm±	0.41	-	-	0.42	0.85
LSD (P=0.05)	1.20	-	-	1.22	

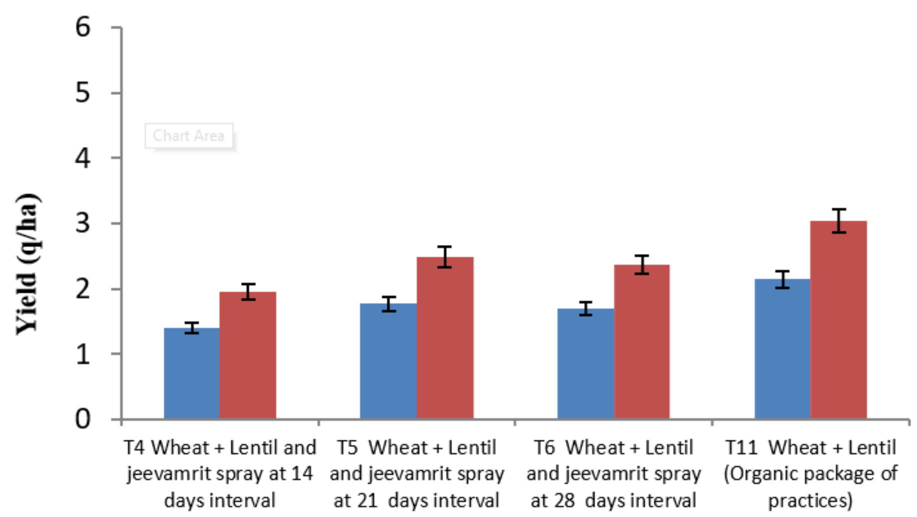

Figure 1) *Effect of treatments on yield of lentil crop;* **Note:** (■) *Seed yield (q/ha)*, (■) *Straw yield (q/ha)*

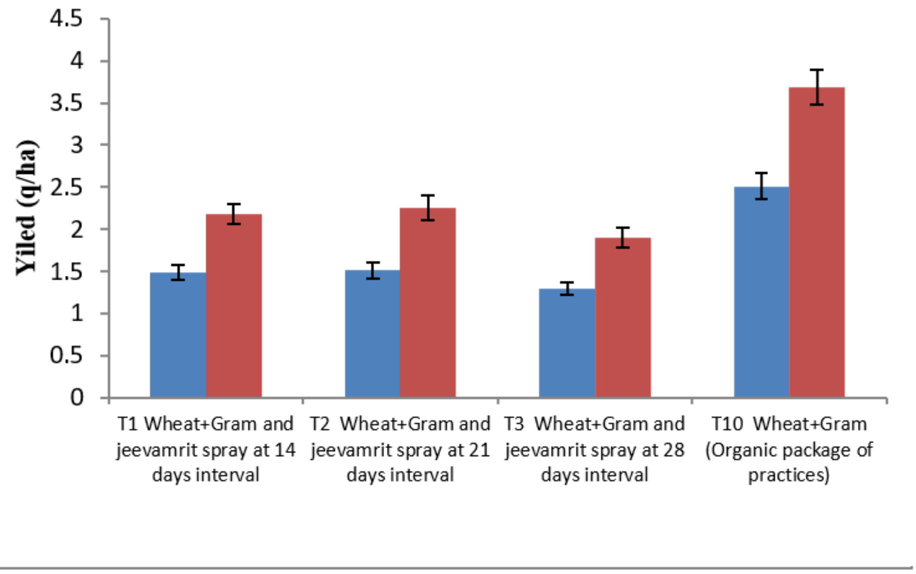

Figure 2) *Effect of treatments on yield of gram crop;* **Note:** (■) *Seed yield (q/ha),* (■) *Straw yield (q/ha)*

CONCLUSION

According to the study's results, farmers should involve legumes in intercropping systems to enrich the soil organic carbon. Wheat intercropped with gram along with application of matka khad at 30 days' interval gave better results for achieving higher productivity main crop as well as intercrop. The higher yield obtained in organic farming treatments might be attributed to the application of FYM. Organic practices yielded promising results, indicating their potential effectiveness as viable approaches for sustainable crop production.

ACKNOWLEDGEMENT

I would like to extend my sincere gratitude to my Advisor Dr. Rameshwar and Department of Organic and Natural Farming for providing me with a conducive academic environment and the necessary resources that made this research possible.

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