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Is Zero-Budget Natural Farming (ZBNF) Viable for Corn Cultivation? A Comparative Study among ZBNF, Organic and Chemical Farming in Corn in South India

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ABSTRACT

Two-season field experiments were conducted with the objective of finding the performance of corn hybrid and cultivar under three different farming methods i.e., Zero Budget Natural Farming (ZBNF), organic farming (OF), and chemical farming (CF) along with control, in Telangana State, Southern India. The experiment was set up in a Factorial Randomized Block Design with three replications. The hybrid (DHM 117) outperformed the cultivar (Ashwini) in terms of growth, yield, economics, and energetics. Corn plants grew taller with higher dry matter accumulation, yield components (cob length, girth, number of kernels per row, and 100 kernel weight), and yields (kernel and stover) in CF compared to OF and ZBNF. While weed growth was lower and soil moisture was higher in ZBNF compared to OF and CF. The yield loss was significantly higher in the hybrid compared to cultivars in OF and ZBNF compared to CF. The yield of hybrid was only 40% and 18.9% of that CF in OF and ZBNF, respectively. Similarly, the cultivar recorded 67% and 28.8% of the yield of CF in OF and ZBNF, respectively. OF used higher energy input (59094 MJ ha-1) and recorded higher specific energy while the energy output was the maximum with CF. The energy productivity and energy use efficiency were superior with ZBNF compared to that in OF and CF. The gross returns realized in OF and ZBNF could not meet the variable costs of cultivation while the benefit-cost ratio in CF was 1.62 with hybrid and 0.2 with cultivar.

Keywords: *Chemical farming, Economics, Energetics, Corn, Organic farming, Yield, Zero Budget Natural Farming (ZBNF)*

INTRODUCTION

The green revolution started in the late 1960's brought agricultural prosperity to India through productivity gains in major crops for feeding its burgeoning population. Over the years, the increased use of fertilizers and other agrochemicals which was one of the pillars of the green revolution was accompanied by the negative effects of deterioration in soil health, progressive rise in multi-nutrient deficiencies, nutrient imbalances, inefficient resource use [1], [2], [3]. Furthermore, detrimental impacts on human health due to the use of agrochemicals have been reported [4], [5]. Hence, a need was felt for a more sustainable and ecologically balanced approach to revive agriculture. Although organic agriculture gained momentum worldwide including in developed countries like USA and Europe, at present only 1.4 percent of the world's agricultural land is under 'official' organic cultivation [6]. On the other hand, climate change has taken its toll of reduced food production in India by 0.8% between 1974 and 2013 [7]. The effects of climate change on our ecosystems are already severe and widespread [8]. Climate change impacts may reduce income levels and stability through effects on productivity, production costs, and prices and the impacts are greatest for the poorest farmers [9], [10]. Proclaiming as a panacea, Padma Shree Subash-Palekar floated the concept of Zero Budget Natural Farming (ZBNF) in India during the 1990's built on the four wheels aiming at the restoration of soil health and microbial wealth.

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Zero Budget Natural Farming (ZBNF) is an agroecological farming approach that promotes growing crops in harmony with nature [11]. It espouses the neo-Gandhian values of self-reliance and autonomy. From its origins as a social movement in 2002 through 2015, ZBNF spread at the grassroots level through the collective efforts of a constellation of peasant members and movement allies, the 'ZBNF' movement in Karnataka State and subsequently to the other States of India, especially in South India [3]. Around 200 trainings and workshops were organized for the farmers in Karnataka. Later on, the movement received the attention of State Governments. Andhra Pradesh attempted to scale up the ZBNF across the State. At the global level also, the farmer's alliance La Via Campesina (LVC) became a major ally of ZBNF through its local member - the Karnataka Rajya Raitha Sangha, many of whose farmers are ZBNF farmers [12].

Basically, ZBNF is a concept that prompts organic farming without the off-farm or market-oriented inputs with ecologically friendly techniques [13]. These are (i) Jivamrita, meaning 'life tonic' is a homemade fermented microbial culture made of water, cow dung and urine, jaggery, legume flour, and a handful of soil preferably from an ant hill as an inoculant of local micro-organisms. Palekar claims that jivamrita application significantly increases earthworm activity and only the dung and urine of indigenous cows (Bos indicus) should be used for making jivamrita because it has a superior microculture compared to that of introduced European breeds [14], [11]. Furthermore, Palekar rejects the introduction of the exotic worm Eisinea feotida in vermicomposting. (ii) Bijamrita: Microbial seed treatment made of similar ingredients as jivamrita. It is effective in protecting seedlings from seed or soil-borne diseases, as well as young roots from fungus. (iii) Acchadana (mulching): ZBNF promotes many types of mulching including soil mulching which protects topsoil by avoiding tilling, straw mulching which adds straw to the soil to enhance decomposition and humus formation through the activity of the soil biota, activated by jivamrita, live mulching like cover cropping, intercropping of monocotyledons and dicotyledons, grown in the same field, to supply all essential elements to the soil and crops [13]. (iv) Whapasa (moisture): is the condition in which there are both air molecules and water molecules present in the soil. Irrigation is encouraged only at noon in alternate furrows. There are also a number of pest management measures such as neemastra, agniastra and brahmastra – which are homemade preparations used for insect pest control, in addition to functioning as fungicides and as 'tonics' [14]. ZBNF differs from organic farming in that the nutrients needed for crop growth are not supplied through manures but through soil microbial inoculum (Jeevamrutha) and mulching aiming to change the functioning of a soil-crop system so that nutrients are made available to crops without the need for external inputs. It uses zero inputs of synthetic fertilizers to avoid reliance on purchased inputs and credit, and low inputs of animal manures to avoid limitations on available manure.

Maize (Zea mays L.) is the world's third most important cereal crop after rice and wheat. As a heavy feeder of nutrients, maize productivity is largely dependent on nutrient management [15], [16], [17]. In India, Maize is cultivated in an area of 9.28 million ha. South Indian states (Karnataka, Kerala, Telangana, Andhra Pradesh, and Tamil Nadu) account for about 30% of the area under maize (2.57 m ha) where ZBNF gained momentum among the farmers. In the wake of all the above, there was a need arose to validate the ZBNF by in the Scientific Community through the experiments in State Agricultural Universities and the Indian Council of Agricultural Research, New Delhi. Research by ICAR-Indian Institute of Farming Systems Research (IIFSR), Modipuram for Palekar's ZBNF in the rice-wheat system in north India showed a reduction in ZBNF yield by up to 40% in the initial years as compared to chemical-based integrated crop management. The study was presented at a National Academy of Agriculture Sciences (NAAS) meeting in August 2019. The NAAS, a think-tank of agriculture scientists in India, said through a policy brief that ZBNF is an unproven technology and no verifiable data or authenticated result from any experiment is available so far. On the contrary, a survey of ICAR's National Academy of Agricultural Research Management, Hyderabad, of ZBNF in Karnataka and Andhra Pradesh, found that ZBNF reduced farming costs, increased farmer income, and had ecological and social benefits. ZBNF yield results were mixed i.e. in some crops it showed higher yield, while in other crops it showed a yield reduction. On the other hand, organic farming has strong scientific data which proved its agro-ecological sustainability. The sustainability of ZBNF is questioned because external nutrient inputs are limited, which could cause a crash in food production even though it is likely to reduce soil degradation [7]. The possible social, economic, and environmental impacts of the Government of Andhra Pradesh-led ZBNF programme vis-à-vis specific targets under each sustainable development goal [18]. They opined that once it is rolled out across the state, ZBNF could help AP and India to make significant progress toward almost a quarter of the 169 sustainable development goals. In view of the above, the present study was conducted to investigate the growth, yield, energetics, and economics of maize in ZBNF vs organic or inorganic farming methods.

MATERIALS AND METHODS

Site description

The experiments were carried out in the rainy (kharif) and post-rainy season (rabi) during 2016-17 in the same plots at Agricultural College, Jagtial, Telangana State, South India. The study site falls under a semi-arid climatic region situated at an altitude of 243.4 m above mean sea level on at 18049'40'' N latitude and 78056'45'' E longitude. In general, the climate of the region is suitable for maize cultivation throughout the year. It experiences monsoon rains from June to September and thereafter a cool and dry climate. The weekly mean minimum and maximum temperatures during the rainy season ranged from 17.7 to 33.4°C, respectively. Mean relative humidity ranged from 51.1 to 93.1% and the wind speed ranged between 1.0 to 6.6 km hr-1 and the evaporation rate ranged from 0.8 to 4.2 mm. A total of 668.5 mm of rainfall was received over 40 rainy days. Correspondingly, the weekly mean minimum and maximum temperatures during the post-rainy season ranged from 19.5°C and 40.7°C, respectively. Mean relative humidity ranged between 53.9 and 74.3% and the wind speed ranged between 0.6 and 3.7 km hr-1 and the evaporation rate ranged from 3.0 to 4.0 mm. A total of 5 mm of rainfall was received during the post-rainy season. The experimental soil was sandy clay loam in texture, neutral in reaction (7.65), normal electrical conductivity (0.074 d Sm-1), and low in organic carbon content (0.47%). The available N, P2O5, and K2O contents were 164, 46, and 277 kg per ha, respectively and the available zinc content is 0.3 ppm.

Plant material

The performance of hybrid (DHM 117) vs cultivar (Aswini) is studied in the present study as it was advocated to use the seeds of indigenous cultivars in the principles of ZBNF to avoid the purchase of external inputs and seeds from outside the farm. Thy maize hybrid viz., Deccan Hybrid Maize 117 (DHM 117) was released from the All India Coordinated Research Project on Maize (Indian Institute of Maize Research), Hyderabad, India in 2009. It is of 90-100 days duration, suitable for both rainy and post-rainy cultivation in Telangana, Andhra Pradesh, Karnataka, Tamil Nadu, and Maharastra States. The cultivar viz., Aswini is a composite that was released from Acharya NG Ranga Agricultural University in 1988. This is medium medium-maturing composite has orange-yellow, semi-dent grains and suitable for both rainy and post-rainy cultivation in Telangana and Andhra Pradesh States.

Experimental design and treatments

The experiment was laid out in randomized block design with a factorial concept and replicated thrice. Eight treatment combinations were taken viz., factor I: Hybrid vs cultivar: 2 (V1: DHM-117, V2: Aswini), factor II: Farming methods: 4, F1: Control (no fertilizers or manures), F2: Zero Budget Natural Farming (Seed treatment with Beejamrutha + application of Jeevamrutha at fortnightly intervals + mulching with organic residues + plant protection with natural pesticides/fungicides like Neemastram, Agnastram, and Pullatimajjiga (Fermented butter milk), F3: Organic farming [FYM @ 20 t ha-1 (basal) + Vermicompost @ 5 t ha-1 each at knee high stage and tasselling stage (top dressing) + plant protection with organic products + manual weeding] and F4: Chemical farming (200:60:50 kg ha-1 of N:P2O5:K2O through urea, di ammonium phosphate and muriate of potash + pest and weed control with chemical based pesticides).

Sowing

The maize seeds were sown at 60 cm x 20 cm in a plot area of 43.2 m2 with 12 rows per plot. During the post-rainy season, the plots were not disturbed and were assigned with the same set of treatments as done in the rainy season. Field preparation was done with a small rotary tiller followed by leveling with hand hand-operated implements. A seed rate of 20 kg ha-1 was adopted. Thinning and gap filling were done 12 days after germination and one healthy seedling per hill was were maintained. The crop was principally raised with incident rainfall with supplementing irrigation water during the rainy season whereas totally under irrigation during post rainy season.

Different formulations used in ZBNF were prepared as per the protocols described by [20]. Beejamrutha was prepared by mixing 5 kg desi cow dung, 5 liters of desi cow urine, 50 g lime, and 100 g soil from ant hill with 20 liters of water and kept overnight for fermentation. On the day of sowing, maize seeds were soaked in the Beejamrutha solution and dried in the shade before sowing. Jeevamrutha was prepared by placing 200 liters of water in a barrel and adding 10 kg fresh desi cow dung, 10 liters of desi cow urine, 2 kg each of jaggery and chickpea flour, and 100 g of soil from an ant hill. The mixture was fermented for 3 days in shade conditions. It was used for spraying in the field after filtering. Mulching was done with the use of paddy straw (8-inch layer) when the crop was at the 3-4 leaf stage. Neemasthram was prepared by mixing of 10 liters of cow urine, 5 kg of cow dung, and 10 kg of neem leaves (Azardiracta indica) in 200 liters of water and fermented for 5 days in shade condition. This fermented solution was applied as repellent in the form of a spray. Agnasthram was prepared by mixing the 10 kg neem leaves paste, 3 kg tobacco leaf powder, 3 kg garlic paste and 4 kg green chillies paste. In control treatment and organic farming methods, the weeds were controlled by hand weeding at 10 days intervals up to 50 DAS. While in ZBNF, mulch acted as a weed suppressor. Pre-emergence application of atrazine 50% WP @ 3.75 kg ha-1 with hand weeding at 10 and 40 DAS was practiced in the chemical farming method.

Fertilizer management in natural farming through the basal application of ganajeevamrutha (solid form) @ 500 kg ha-1 was followed by Jeevamrutha (liquid form) @ 500 L ha-1 along with irrigation water starting from 15 DAS till harvest at 15 days interval. When rainfall occurred, it was sprayed directly on the soil through a knapsack sprayer. While in organic farming, FYM was applied basally @ 20 tonnes ha-1 and vermicompost was applied @ 5 tonnes ha-1 each at knee high and tasseling stages and in chemical farming, a recommended dose of 200:60:50 kg ha-1 of N:P2O5:K2O through urea, di-ammonium phosphate and muriate of potash was applied, respectively. Nitrogen and potassium were applied in three equal splits i.e., as basal dose, at knee high, and at flowering stage. The recommended dose of phosphorous was applied as a basal dose.

Data collection

Plant height was measured from ground level to the tip of the upper node just below the tassel. The average height of five plants was recorded from each plot. Plant samples were collected (excluding root) at 60 days after sowing (DAS) and 90 DAS and shade dried for one week then shifted to the hot air oven at 65°C till it reaches constant dry weight. Soil moisture content was estimated by gravimetric method at fortnight intervals from sowing to harvest in the top 30 cm depth and expressed in percent. The yield attributes like the number of cobs plant-1, length of the cob, the girth of the cob, no of kernel rows cob-1, number of kernels cob-1, weight of cob, weight of kernels cob-1 and test weight were recorded at harvest. The observations of five plants were averaged and expressed on a per per-plant basis. The cob weight and kernel weight were recorded after they were dried up to 12% moisture. The cob length was recorded from the base to the tip of the cob by marking the points on the graph paper for five cobs and expressed as cm. The girth was measured with vernier calipers and was expressed in cm. The number of rows in each cob was counted manually. The kernel sample was taken from each net plot to compute 100 kernel weight and expressed in grams. The weight of the cob, grain, and stover were was recorded at 12% moisture.

Economics and Energy Parameters

Gross returns, net returns, and benefit-cost ratios were calculated based on the prevailing wages and market prices for the inputs and outputs. The input energy and output energy were calculated using the energy equivalents given in Table 1 and the energy productivity, specific energy, and energy use efficiency were estimated as per the following formulae:

Energy productivity = Energy output (Kg/ ha)/ Energy input (MJ/ha) Specific energy = Energy input (MJ/ ha)/ output (Kg/ ha)

Energy use efficiency = Energy output (MJ/ ha)/ Energy input (MJ/ ha)

Statistical analysis

The data were analysed statistically by applying the analysis of variance technique for randomized block design (RBD) with the factorial concept [19]. Critical difference for examining the treatment means for their significance was calculated at 5 per cent level of probability.

RESULTS AND DISCUSSION

Growth parameters and weed growth

Maize plants grew taller in chemical farming compared to other methods and hybrid was superior to cultivar (Table 2). Similarly, organic farming was superior to ZBNF. In both the hybrid and cultivar; tassels appeared much later in ZBNF compared to organic and chemical farming but for silking the differences were not significant (Table 2). Weed count and weed dry matter recorded at 30 and 60 DAS were much lower in ZBNF than that of in organic and chemical farming (Table 3). The lower weed infestation is due to the mulching with paddy straw in between the maize rows, which is described as one of the pillars of ZBNF i.e., Achadana. However, the weed parameters were not statistically different between hybrid and cultivars.

Soil moisture dynamics and dry matter production

Soil moisture content (%) measured at fortnightly intervals revealed that it was not much different among the farming methods during the rainy season (Figure 1) but was markedly higher with ZBNF throughout the growth period of maize during the post-rainy season (Figure 2). The higher moisture content (11.3 to 14.7%) in ZBNF could be due to the mulching with organic material (paddy straw). The average dry matter produced in DHM 117 at 60 DAS (3955 kg/ha) was 36% higher than that of the cultivar i.e., Aswini (2911 kg/ha). At harvest, the difference rose to 51% between the hybrid and cultivar (Table 4). The highest dry matter was accumulated at harvest in DHM 117 with CF (21399 kg/ha). The difference between hybrid and cultivar in CF was 74% while it was 21, 41, and 73 percent in OF, ZBNF, and control, respectively.

Yield components and yield

All the yield components like cob length, girth, number of kernels/row, and 100 kernel weight were significantly higher in the hybrid over those in the cultivar except for the number of kernel rows/cob while the measured values of the above parameters were the lowest in control. Among the farming system, superior values for all the yield components were obtained in CF over OF and ZBNF (Table 5). Similarly, the yield components in OF were statistically superior to those in ZBNF. The interaction between the hybrid vs cultivar and farming method was significant for kernel number (Table 2). They were significantly higher in DHM 117 with CF. On the other hand, the kernel number and weight per cob were reduced in OF over CF and again from OF to ZBNF.

The average kernel yield in hybrid (DHM 117) was 2247 kg/ha across two seasons and farming methods including control (Table 5) which was 159% higher than that obtained in cultivar (Aswini). The average yield of DHM 117 in OF was 40% and 18.9% in ZBNF of that obtained in CF. Correspondingly, the yield of the cultivar (Aswini) in OF was 67%, and in ZBNF was 28.8% of that realized in CF. From this, it is apparent that the maize hybrid suffered a huge yield reduction due to OF and ZBNF compared to the cultivar. In A comparison of four early maize varieties in conventional vs low-input farming in Italy and found that all the agronomic parameters including yield were better in conventional farming [20]. In voraciously feeding crops like corn, low-input systems like ZBNF may not supply enough quantities of nutrients during the initial period of conversion. Hence heavy yield penalty was realized. The yield challenges in the ZBNF are likely to provide yield benefits for low-input crops and farms [7].

It is pertinent to mention that an average yield of 255 kg/ha was produced in control wherein nutrients were not applied through any source. In ZBNF, the average maize yield was 197% higher than the control. It suggests that although the yield production suffered a setback in ZBNF, the principles of the farming method certainly had their effect but might not be in tune of with a sufficient supply of nutrients. Organic farming resulted in 548% increase in kernel yield over control. There was a general trend of better yields from conventional farming over low low-input farming in maize hybrid and varieties [20]. A similar trend was also evident for stover yield (Table 5). It was 67.5 and 54.0 percent of CF realized with OF and ZBNF, respectively in hybrid, while 67.8 and 41.7 percent of CF were only produced in Aswini with OF and ZBNF, respectively. The major difference among the farming methods was with respect to the source of nutrient supply, weed management, and pest control. Application of jeevamrutha, one of the basic inputs in ZBNF, alone showed poor plant growth and yield in maize and rice, respectively [21], [22]. There was an enhanced yield, uptake of nutrients, and economics in maize when jeevamrutha and beejamrutha were amended with 100% N equivalent compost and FYM at 10 t/ha [23]. The yield trends on conversion to ZBNF and opined that in low-input systems, nitrogen supply is expected to increase with conversion to ZBNF hence leading to improved yield than in the cropping systems of high-income, high-input farmers [24]. Finger millet, a very low input crop under conventional farming gave a better yield in ZBNF but in high input crops (paddy, sugarcane, soybean, sorghum, cotton, and turmeric), the yield loss was up to 30% to that obtained in chemical farming [25]. A researcher conducted crop-cutting experiments in Andhra Pradesh and found that all crops (rice, groundnut, finger millet, and other millets) except irrigated maize and irrigated cotton showed higher yields under ZBNF relative to a non-ZBNF fields [26].

Economics

The total cost of cultivation (COC) of DHM 117 ranged from ₹ 16900 to ₹ 71500 per ha while it was from ₹ 14300 to ₹ 68900 per ha in Aswini (Table 6). The highest cost was incurred in OF owing to the escalated costs of manure and other organic inputs during the last decade. The gross returns through kernel and stover were meager in control and ZBNF and could not meet the COC, hence turned into a negative B:C ratio in both hybrid and cultivar while the greater loss in invested cost was for of in which B:C ration was negative by 0.56 and 0.75 in hybrid and cultivar, respectively. Positive net returns and B: C is are obtained in CF with hybrid (1.62) but the magnitude of benefit was meager in cultivar (0.2). Evidences collected in the Purulia district of West Bengal revealed that ZBNF farmers have experienced a reduction in per hectare yield for their crops in the post-conversion period [27]. In contrast, an experiment in groundnut in Karnataka state and economic analysis revealed that the B:C ratio was found to be more in ZBNF (1.66) than OF (1.58) due to the high cost for purchase of FYM in OF [26]. Thus recommended package of practices was the best with respect to yield and B-C ratio. The cost of cultivation was reduced in ZBNF by 23.7 per cent while the gross income and net income of ZBNF farmers rose by 14.2 and 50 per cent, respectively in Andhra Pradesh state [26]. The survey of 639 ZBNF farmers across six agro-climatic zones of Andhra Pradesh reported a potential for a reduction in fertilizer consumption and reduced production costs [28]. A study in Karnataka state reported that the ZBNF system performed well in millets cultivation under the a rainfed situation [29]. Around 92 percent of the farmers experienced that the cost of cultivation under ZBNF was minimized. B:C in ZBNF improved significantly in paddy, sugarcane, and finger millet owing to less input- cost and attracting premium prices for chemical-free produce.

Energy parameters

Energy inputs and outputs are presented in Table 6. The total energy consumption was higher in OF (59094 MJ ha-1) owing to the use of large quantities of manures for the supply of the nutrients. ZBNF used less energy compared to OF and CF in both hybrid and cultivars. The energy output was the maximum with CF (169473 and 59415 MJ ha-1, in hybrid and cultivar, respectively). But the energy productivity and energy use efficiency was higher with ZBNF compared to OF and CF, while specific energy was the maximum with OF in both hybrid and cultivar. The energy output and energy productivity were higher in conventional production compared to the organic system [30] and the energy use efficiency in ZBNF was 4.83 MJ per ha in rice crop [31].

Table 1. Energy conversion factors used in the study

Input	Units	Equivalent energy (MJ)
1. Human labour		
Man	h	1.96
Women	h	1.57
2. Machinery		
Machine labour	h	62.70
Farm Machinery	h	49.66
3. Maize seed	kg	14.7
4. Fertilizers		
Nitrogen	kg	66.44
Phosphorus	kg	12.44
Potassium	kg	11.15
5. Organic manures		
FYM	kg	0.3
Vermicompost	kg	10.5
6. Chemicals		
Herbicides	kg	238
Pesticides	kg	199
Fungicides	kg	92
7. Bio fungicides	L	10.10
8. Bio insecticides	L	21.60
9. Knapsack sprayer	h	0.5
Output energy		
Maize kernel and stover	kg	17

Source: [5], [4], [23], [30],[21]

Table 2. Growth parameters of corn as influenced by different farming methods

Treatment	Plant height (cm)	Number of days to tasseling	Number of days to silking	Cob length (cm)	Cob girth (cm)	No. of kernel rows per cob	No. of kernels per row	100 kernel weight (g)
DHM-117	215.5	62	68	10.93	11.90	11.70	18.19	24.26
Aswini	186.0	61	68	8.74	10.15	10.45	15.45	17.95
SEm±	5.3	0.5	0.5	0.40	0.25	0.30	0.55	0.55
CD (P=0.05)	15.9	NS	NS	1.10	0.75	NS	1.70	1.65
Control	148.5	67	74	5.15	7.40	6.45	7.30	16.78
Natural Farming	184.5	63	69	9.05	10.40	9.90	15.10	20.68
Organic Farming	215.7	59	65	11.25	12.15	13.00	19.25	21.86
Chemical Farming	254.2	58	64	13.95	14.05	15.15	25.50	24.89
SEm±	7.4	0.75	0.8	0.40	0.35	0.45	0.78	0.77
CD(P=0.05)	22.5	1.35	NS	1.20	1.05	1.30	2.37	2.34
Interaction								
SEm±	10.5	1.2	1.2	0.60	0.50	0.60	1.10	1.09
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

CONCLUSION

The results of the investigation indicated that shifting to ZBNF seems not viable for corn cultivation during the infancy of conversion, especially for hybrid and chemical farming was the best option compared to ZBNF and organic farming in terms of yield and economics. Further work will be necessary to validate the findings of this study including the ecological, economic,al and environmental impacts on a long-term basis.

AUTHOR DECLARATIONS

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Conflicts of interest/Competing Interests

The authors declare no conflict of interest associated with this article

Consent for publication

The necessary permission is taken from Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India

Availability of data and material/ Data availability

All data generated or analyzed during this study are included in this published article.

Author's Contribution

Conceptualization, investigation, and original draft preparation - M. Mallareddy.; Revision of original draft - G. Jayasree. and S. Vijayakumar.; Data collection and data entry – G. Vinay. and G. Padmaja.; Statistical analysis and Tabulation - B. Padmaja. All authors read and approved the final manuscript.

Table 3. Weed density and weed dry matter in corn as influenced by different farming methods

Treatment	Weed density (Number m^{-2})				Weed dry matter (g m^{-2})			
	30 DAS		60 DAS		30 DAS		60 DAS	
	Rainy	*Post rainy season*	*Rainy*	*Post rainy season*	*Rainy*	*Post rainy season*	*Rainy*	*Post rainy season*
Cultivar Vs hybrid								
DHM 117	6.75 (51.50)	7.31 (61.75)	6.55 (45.21)	7.00 (59.00)	3.69 (16.67)	3.51 (12.83)	5.31 (33.34)	4.07 (17.72)
Aswini	6.06 (39.83)	7.30 (61.25)	6.65 (46.13)	7.14 (59.75)	3.85 (17.33)	3.64 (13.54)	5.62 (37.92)	4.05 (17.16)
SEm±	0.31	0.22	0.30	0.10	0.15	0.09	0.17	0.06
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Farming method								
Control	9.28 (88.33)	10.24 (103.83)	8.47 (71.92)	12.34 (151.33)	6.20 (38.75)	4.73 (21.42)	7.96 (64.67)	6.15 (36.90)
ZBNF	4.49 (22.17)	2.62 (7.00)	6.42 (41.33)	3.70 (12.83)	1.87 (3.88)	1.73 (2.22)	1.73 (3.17)	2.29 (4.32)
Organic farming	6.43 (43.33)	9.46 (88.67)	6.16 (38.08)	6.37 (39.67)	3.84 (14.87)	4.33 (17.33)	6.61 (43.72)	4.09 (15.75)
Chemical farming	5.43 (29.83)	6.89 (46.50)	5.34 (31.33)	5.88 (33.67)	3.17 (10.10)	3.52 (11.38)	5.55 (30.97)	3.71 (12.78)
SEm±	0.44	0.31	0.42	0.15	0.22	0.13	0.24	0.08
CD (P = 0.05)	1.35	0.93	1.29	0.44	0.66	0.39	0.72	0.24
Interaction								
SEm±	0.63	0.43	0.60	0.21	0.31	0.18	0.34	0.11
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	17.01	10.28	15.74	5.06	14.06	8.90	10.71	4.81

Table 4. Dry matter production (kg ha-1) of corn as influenced by different farming methods

Hybrid/ cultivar	Farming method															
	Control				Natural Farming				Organic Farming				Chemical Farming			
	at 60 DAS		at harvest		at 60 DAS		at harvest		at 60 DAS		at harvest		at 60 DAS		at harvest	
DHM 117	1758		5738		2838		9934		4462		11511		6762		21399	
Aswini	1217		3322		2731		7032		3508		9497		4187		12330	
Mean	1487		4530		2784		8483		3985		10502		5475		16864	
Factors	SEm±	P=0.05	SEm±	P=0.05	SEm±	P=0.05	SEm±	P=0.05	SEm±	P=0.05	SEm±	P=0.05	SEm±	P=0.05	SEm±	P=0.05
Farming method	109	330	437	1326	109	330	437	1326	109	330	437	1326	109	330	437	1326
Variety/ Hybrid	77	233	309	937	77	233	309	937	77	233	309	937	77	233	309	937
Interaction	154	467	618	1875	154	467	618	1875	154	467	618	1875	154	467	618	1875

Table 5. Yield components and yield of corn as influenced by different farming methods

Hybrid/ Cultivar	Number of kernels per cob					Kernel weight per cob (g)				
	Farming method					Farming method				
	C	NF	OF	CF	M	C	NF	OF	CF	M
DHM 117	48.7	146.0	231.7	401.7	207.24	32.32	78.65	166.91	290.13	142
Aswini	44.7	119.4	197.5	279.0	160.15	23.34	56.33	95.30	175.07	88
Mean	46.9	132.7	214.8	340.3		27.83	67.49	131.11	232.60	
Factors	SEm+	CD (P=0.05)				SEm+	CD (P=0.05)			
Farming method	10.5	31.6				4.40	13.36			
Hybrid/Cultivar	7.2	22.1				3.11	9.45			
Interaction	14.85	44.8				6.23	18.89			

Hybrid/ Cultivar	Kernel yield (kg ha-1)					Stover yield (kg ha-1)				
	Farming method					Farming method				
	C	NF	OF	CF	M	C	NF	OF	CF	M
DHM 117	416	1022	2142	5410	2247	2841	4639	5808	8598	5471
Aswini	95	496	1162	1723	869	693	1659	2697	3977	2256
Mean	255	758	1652	3566		1767	3149	4252	6288	
Factors	SEm+	CD (P=0.05)				SEm+	CD (P=0.05)			
Farming method	70	213				155	472			
Hybrid/Cultivar	50	151				110	334			
Interaction	99	301				210	667			

Note: C – Control, NF - Natural Farming, OF - Organic Farming, CF - Chemical Farming, M – Mean

Table 6. Economics and energetics of corn as influenced by different farming methods

Treatment	Cost of cultivation (Rs. /ha)	Gross Returns (Rs. /ha)	Net Returns (Rs. /ha)	B-C ratio	Energy input (MJ ha-1)	Energy output (MJ ha-1)	Energy productivity (kg/MJ ha-1)	Specific energy (MJ/Kg ha-1)	Energy use efficiency (MJ ha-1)
DHM 117									
Control	16900	6037	-10863	-0.64	1129	65348	3.40	0.29	57.87
Natural Farming	24415	14811	-9605	-0.39	2722	98634	2.61	0.38	36.24
Organic Farming	71500	31064	-40437	-0.56	59094	111469	0.14	6.97	1.89
Chemical Farming	29950	78444	48494	1.62	15734	169473	0.99	1.01	10.77
Aswini									
Control	14300	1376	-12924	-0.90	1129	7140	0.47	2.13	6.32
Natural Farming	21815	7188	-14628	-0.67	2722	22355	0.66	1.52	8.21
Organic Farming	68900	16853	-52048	-0.75	59094	36686	0.05	19.75	0.62
Chemical Farming	27350	24989	6622	0.20	15734	59415	0.30	3.30	3.78

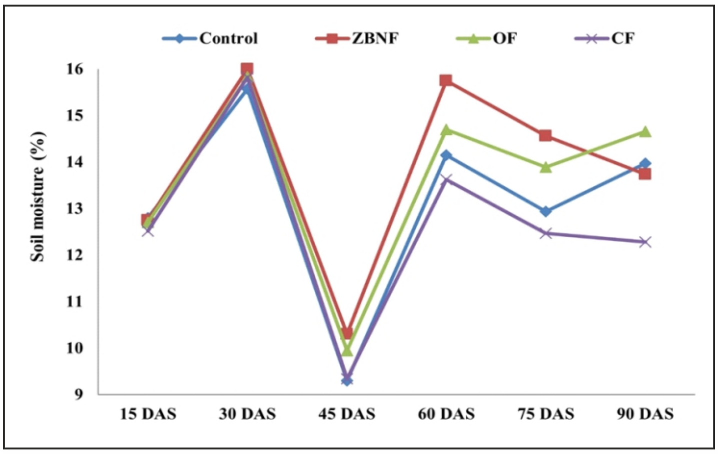

Figure 1. Soil moisture (%) in the top 30 cm layer during rainy season

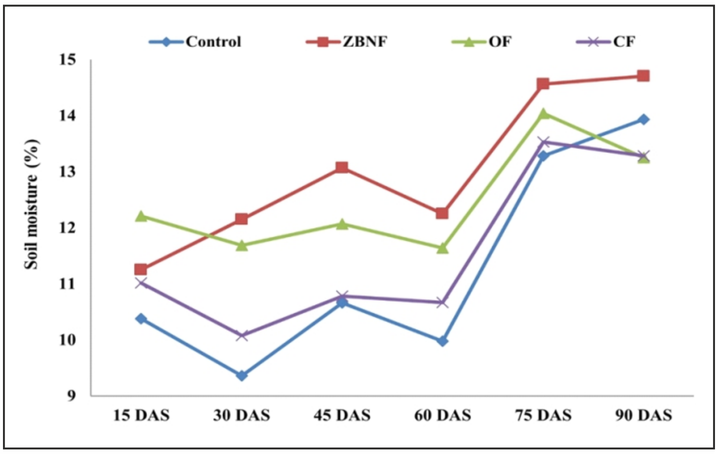

Figure 2. Soil moisture (%) in the top 30 cm layer during post rainy season

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