Original Research Article

Validation Of Different Natural Farming System And Its Impact On The Yield Of Great Millet (*Sorghum bicolor* L.)

ABSTRACT

The most recent and popular trend of organic agriculture in Indian farming system is Zero Budget Natural Farming (ZBNF) that is derived from the traditional method of cultivation practices. ZBNF approach follow practices *viz*., Intercropping, green manure incorporation, crop rotation, composting and degradation of agro-wastes and biocontrol of pests and diseases. Field trial was conducted in two consecutive years, with seven treatment options in randomized block design for validation of different natural farming system such as ZBNF approach, Network Project on Organic Farming (NPOF) and Integrated Crop Management (ICM) practices. Sorghum intercropping with cowpea (1:1) and ZBNF practices involving the application of traditional organic biostimulants such as *Bijamri~~ir~~th* + *~~Gnanajeevamirth~~Ghanajeevamrith* + *Jeeva~~mirth~~mrith* with mulching (*Acchadana*)(T_4) resulted in higher benefit cost ratio of 3.78 and closely followed by sorghum intercropping with cowpea (1:1) and ZBNF practices (*Bija~~mirth~~mrith* + *~~Gnanajeevamirth~~Ghanajeevamrith* + *Jeeva~~mirth~~mrith*) (T_3). Significantly higher grain yield of sorghum (2405 kg ha^{-1}) was recorded in Integrated crop management (ICM-II) practices involving 50 % organic manures + 50 % inorganic fertilizers with need based traditional organic pesticides such as *Neemastra*, *Agniastra*, *Brahmastra*. The findings of the field level validation of ZBNF practices on yield of sorghum intercropping with cowpea suggest that there is an assured initial yield impact when converting to ZBNF compared to organic or conventional systems.

Keywords:*Natural farming, ZBNF, Sorghum, Intercropping, Cowpea, Grain yield*

1. INTRODUCTION

Agricultural production has tripled since green revolution technologies. In the post green revolution indiscriminate use of toxic herbicides, insecticides, fertilizers has negatively influenced soil biochemical properties (Al-Daikh*et al.,* 2016; Ghosal and Hati, 2019). Zero Budget Natural Farming (ZBNF) is derived from one of the traditional methods and it is a type of organic farming agriculture, which gained momentum in recent times in India. It was practiced first in Karnataka state, India by the founder Subhash Palekar and gained momentum among the marginal and small land holding farmers (Khadse*et al.,* 2018)

In ZBNF nothing has to be purchased from outside. The principal methods of ZBNF include crop rotation, green manures and compost, biological pest control, and mechanical cultivation. The most popular and main pillars of ZBNF products derived from the concoction of desi cow urine and dung in different proportions and methodology of preparation. The most popular and main pillars of ZBNF products derived from the concoction of desi cow urine and dung such as *Bija~~mirth~~mrith* (Organic formulation made from cow urine, dung / microbial coating of seeds with formulations of cow urine and cow dung. *Bija~~mirth~~mrith* is Sanskrit word meaning organic formulations for seed treatment) *Jeeva~~mirth~~mrith*(*Jeevamrutham* is made of two words derived from Sanskrit namely *Jeeva* and *Amrutham.* The word "*Jeeva*" means a living being and "*Amrutham*" means the elixir (medicine) upto extending life. According to agricultural view, *Jeevamrutham* is for crop life and best organic formulation to increase the count of microorganisms. *Jeeamrut*, is a microbial culture, mainly prepared from cow dung and cow urine generally used in organic farming to meet the nutritional requirement of crops). *~~Gnanajeevamirth~~Ghanajeevamrith*-Dry*Jeeva~~mirth~~mrith)*, *Acchadana* (Mulching), *Whapasa*(Moisture) and *Astras* (Botanical extracts for pests) Khadse and Rosset*,* 2019)

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*Bija~~mirth~~mrith*is used as a treatment option of seed/seedling/planting material to reduce mortality rate and ensure vigorous crop growth and by suppressing various seed and soil borne diseases of younger seedlings. *Jeeva~~mirth~~mrith* is basically a kind of bio-fertilizer which adds nutrients to the soil for plant uptake. *~~Gnanajeevamirth~~Ghanajeevamrith* is a dry form of *Jeeva~~mirth~~mrith*and is used in situations of labour and water crisis. Inputs like *Bija~~mirth~~mrith*, *Jeeva~~mirth~~mrith*, *~~Gnanajeevamirth~~Ghanajeevamrith*are advocated for soil and plant nutrition. *Acchadana*means covering or mulching the soil with plant materials for protecting soil from erosion. Besides, it improves soil aeration and conserves soil moisture by checking evaporation loss and weed emergence to some extent is checked through mulching. Further, organic typesof mulches such as dried plants additionally produce humus on decomposition, which supplies nutrients to the crop. Mulching techniques are for weed management. *Whapasa* means moisture retention which focuses on improving water use efficiency by reducing the quantity and frequency of irrigation water applied as only a limited amount of water is needed for the crop growth. *Astras* such as *Agniastra*, *Brahmastra* and *Neemastra* are natural and purely organic plant protection biopesticides that needs scientific scrutiny for large scale recommendation. Most of these inputs required for the growth of the plant are available around the root zone of the plants which reduces the dependency on external resources. Only 1.5 to 2.0 percent is being taken up by the plant while the remaining 98 to 98.5 percent nutrients are taken from air, water and solar energy. Every green leaf of any plant produces 4.5 g of carbohydrates per square feet area, from which we get 1.5 g of grains or 2.25 g of fruits. For preparing this output, the plants take necessary elements like air, water and solar energy from the nature as reported by Mr.Subhash Palekar, the discoverer of theories, principles and methods of ZBNF that induces the indigenous soil microflora to participate in the plant growth activities. The methodical application of organic amendments helps in building up a suitable environment for these organisms to withstand the changes (Megir and Paulus, 2011). *Panchgavya* is a product derived from cattle waste and by-products, that improves soil fertility by increasing organic matter, macro and micronutrient levels, and the uptake of nutrients in plants, promoting the growth and reproduction of micro-organisms and maintaining good soil health (Komal *et al*., 2022).

Cowpea (*Vigna unguiculata*) intercropping with cereals and millets had been extensively studied under arid regions, irrigated/rainfed conditions extensively, but cowpea is the most pest invasive crop and less studied with respect to zero budget natural farming practices. Hence, this study was carried out for comparison and field level evaluation for the feasibility of sorghum intercropping with cowpea to different natural farming systems *viz*., zero budget natural farming, organic farming and conventional farming and assessing its impact on the yield of sorghum.

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2. MATERIAL AND METHODS

2.1.Seed material, sowing, treatment details and study site characteristics

The seed material such as Sorghum CO 30 and Cowpea Co (CP) 7 variety was procured from the Department of pulses and Department of millets, Tamil Nadu Agricultural University (TNAU), Coimbatore, Tamil Nadu, India. The field experiment was carried out at the Eastern block farm, TNAU, Coimbatore in two seasons in the year 2020-2022. The initial soil characteristics were examined for pH, EC, macro nutrients and organic carbon content. The sorghum seeds were placed at the sides of the ridges at 3 cm depth with a spacing of 15 cm between seeds in the rows which are 45 cm apart. Cowpea intercrop was raised in rows in the furrow in between sorghum (one sorghum: one cowpea row).

2.1.1.The treatments for the field experiment were as follows:

Control **(T_1):** Conventional farming with no inputs

Sorghum intercropping with Cowpea (1:1) and ZBNF practices (*Bija~~mirth~~mrith* + *Jeeva~~mirth~~mrith* + *~~Gnanajeevamirth~~Ghanajeevamrith* + *Whapasa*+ *Acchadana*along with cowpea Intercropping **(T_2)**

Sorghum intercropping with Cowpea (1:1) and ZBNF practices (*Bija~~mirth~~mrith* + *~~Gnanajeevamirth~~Ghanajeevamrith* + *Jeeva~~mirth~~mrith*) **(T_3)**

Sorghum intercropping with Cowpea (1:1) and ZBNF practices (*Bija~~mirth~~mrith* + *~~Gnanajeevamirth~~Ghanajeevamrith* + *Jeeva~~mirth~~mrith* + *Acchadana* **(T_4)**

All India NPOF package - FYM with Vermicompost+*Panchagavya* foliar spray + Fish Meal trap, Neem Seed Kernal Extract (NSKE) or Neem oil + 3G extract / *Agniastra* spray **(T_5)**

Integrated Crop Management (ICM)-I (50 % organic manures + 50 % inorganic fertilizers with need based chemical pesticide) **(T_6)**

Integrated Crop management (ICM-II) (50 % organic manures + 50 % inorganic fertilizers with need based *Neemastra*/ *Agniastra*/*Brahmastra***(T_7)**

2.2.Nutritional composition of ZBNF components

The organic inputs *viz*., *bija~~mirth~~mrith*, *jeeva~~mirth~~mrith* and *~~gnanajeevamirth~~Ghanajeevamrith* were analysed for pH, EC, macro nutrients, and organic carbon contents.

2.2.1.Yield attributing parameters and Benefit Cost Ratio

Three plants were selected at random in the net plot area, tagged and used to record growth and yield attributing parameters. Plant height was measured from the ground level to the tip of the growing point, while the leaf length was measured from the tip of the entire leaf down to the base of the leaf and expressed as centimeter. Yield attributing parameters *viz*., number of tillers, plant biomass, earhead length, girth, weight and individual spike weight were recorded in tagged plants in each replicate and mean of the data calculated. The cost of inputs and economic returns from different treatment combinations were recorded. The gross returns were arrived by multiplying the sorghum grain yield from various treatments with the unit price and production cost. Benefit cost ratio was evaluated by dividing the gross return with production cost.

2.2.1.2. Statistical analysis

Data were presented as mean ± standard deviation performed in duplicate. Statistical analysis was performed using the IBM SPSS 23.0 software (SPSS, Chicago, USA). One-way analysis of variance (ANOVA) followed by the Duncan test was used to compare group means. Differences were considered significant if $p < 0.05$. The yield data and soil nutrient parameters are the pooled mean of data obtained from two consecutive years.

3. RESULTS AND DISCUSSION

3.1. Inputs and soil characteristics

Chemical characteristics of the organic inputs and soil are presented in table 1. From the observed data, the initial soil showed neutral pH and medium level of Electrical Conductivity (EC). The available nitrogen, phosphorus, potassium and organic carbon were categorized as low, high, and low, respectively. On the other hand, *bija~~mirth~~mrith*and *~~gnanajeevamirth~~Ghanajeevamrith* reported neutral pH (7.08 and 7.20) whereas the *jeeva~~mirth~~mrith*showed acidic pH of 4.10. The EC ranged from 2.28 to 8.26 dSm^{-1}, the total NPK content was observed high in *jeeva~~mirth~~mrith*. The organic carbon ranged from 0.93 to 17.3 percent *bija~~mirth~~mrith*and *~~gnanajeevamirth~~Ghanajeevamrith*respectively.

Table 1. Chemical characterization of initial soil and ZBNF organic inputs

Parameters	pH	EC (d Sm^{-1})	N	P	K	Organic carbon (%)

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Soil	7.74	0.62	75.3 (kg ha^{-1})	38.0 (kg ha^{-1})	92.4 (kg ha^{-1})	0.47
Jeeva~~mirth~~mrith	4.10	2.28	1.80 (%)	0.42 (%)	1.10 (%)	1.53
Bija~~mirth~~mrith	7.08	8.26	2.38 (%)	0.13 (%)	0.49 (%)	0.93
~~Gnanajeevamirth~~Ghanajeevamrith	7.20	2.68	2.00 (%)	0.46 (%)	0.10 (%)	17.3

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Influence of treatments on growth parameters

The pooled mean data of trials conducted in two consecutive years are given in table 2. The results showed that sorghum recorded higher plant height with application of T_7 (161.4 cm) followed by T_4 (155 cm) showing a significant difference compared to control treatment. Notable changes in leaf length were recorded, while the maximum leaf length was found in T_7 followed by T_6 (78.3) cm and 78.2 cm, respectively. Significant results were observed in the number of tillers per m^{-2}, higher tillers were reported in T_4 and the least was found with control. The reported stover yield was significantly higher in T_4 and lower in control (T_1) with 7.50 kg m^{-2} and 2.50 m^{-2}, respectively. The treatment, T_4 reported significantly higher plant biomass of 3.1 kg m^{-2} followed by T_2 with 2.8 kg m^{-2} of plant biomass and the lowest was observed in control (1.5 kg m^{-2}). More equal distribution of nutrients at the root zone was a benefit for higher absorption of nutrients and increasing the content in grains and straw. Increased grain and straw content increased dry matter production and, as a result, grain and straw absorption of N, P, and K. Higher biomass production may be credited as the most significant thought for increased nutrient intake.

3.1.1. Influence of treatments on yield parameters

The data revealed that the treatments have shown significant differences in all the yield and yield attributing parameters (Fig. 1). Natural farming practices and ZBNF practices (T_4) have produced higher earhead length of 25.82 cm whereas sole natural farming practices (T_3) and control (T_1) showed the lowest earhead length of 18.5 cm. All India NPOF package (T_5) reported significantly higher individual spike weight (0.92 kg) and 1000 grain weight (34.5 g) whereas the lower was found in control (0.36 kg and 20.8 g, respectively). ICM (50 % organic + 50 % inorganic with need based *Neemastra*, *Agniastra, Brahmastra*(T_7) reported significantly higher earhead girth (7.71 cm), earhead weight (0.87 kg m^{-2}), grain weight per earhead (128.19 g), and grain yield (2405 kg ha^{-1}). The higher yield attributes in the above said treatment might be due to greater nutrient availability and better absorption of nutrients by the plants. This might be also due to higher microbial activity resulting in timely release of nutrients along with addition of organic inputs (Binder *et al.,* 2000).

Aulakh*et al*. (2013) had reported in the rice-wheat cropping system that the application of *jeeva~~mirth~~mrith*as a single treatment component resulted in very lower grain yields of rice and wheat of 16 and 49% respectively when compared to inorganic fertilizer application. Amendments with organic preparations in soybean crops resulted in lower yield than the recommended chemical fertilizers (Gowthamchand*et al*., 2019). The results of the present study are in concurrence with the above findings where the ICM practices along with inorganic fertilizers resulted in highest benefit cost ratio compared to ZBNF approach.

3.1.1.2. Influence of treatments on post-harvest soil characteristics (Table. 3)

The analysis of the post harvest soil samples have revealed noticeable results. The reduction in pH has been observed in all the treatments when compared to initial values where ZBNF practices (T_3) showed high pH of 7.42 and Integrated Crop Management (ICM-II) (50 % organic manures + 50 % inorganic fertilizers with need based *Neemastra*/ *Agniastra*/*Brahmastra* (T_7) showed lowest pH of 5.50. Though there have been slight increase in few treatments including organic practices all the EC values have reported to be similar to normal soil values where natural farming practices (T_3) and Cowpea intercropping with sorghum (1:1) and ZBNF practices (*Bija~~mirth~~mrith* + *~~Gnanajeevamirth~~Ghanajeevamrith* + *Jeeva~~mirth~~mrith* + *Acchadana*(T_4) has shown the highest and lowest EC values respectively. Organic Carbon (OC) has been observed to increase in the treatments containing 100 percent organic practices when compared to control and treatments having inorganic practices where natural farming practices (T_3) had shown high OC of 0.85% and ICM (T_7) has shown the lowest OC of 0.36% among the treatments.

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Francisco *et al*. (2023) indicated that organic amendments such as microalgae and compost mixture improved yield in cauliflower cultivation and performed well, even in sandy loam soil when compared to the chemical based fertilizers. In the ZBNF approaches used in the present study, available nitrogen and potassium reported to be increased in all the treatments when compared to initial values where NPOF treatment (T_5) and control (T_1) has shown the highest and lowest values of 140 kg ha^{-1} and 92 kg ha^{-1} respectively. A slight variability has been observed in available P for all the treatments where control (T_1) has shown the lowest available P of 20 kg ha^{-1} and natural farming practices (T_3) has shown highest availability of 50 kg ha^{-1}.

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Table. 2. Effect of ZBNF practices and its impact on yield of sorghum crop

Treatments	Earhead Length (cm)	Earhead Girth (cm)	Earhead Weight (kg m^{-2})	Individual spike weight (kg)	Grain weight per Earhead (g)	1000 Grain weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg/ha)	BCR
T_1	18.5 (± 0.67)	6.79 (±0.26)	0.30 (±0.01)	0.36 (± 0.02)	70.6 (± 3.08)	20.8 (± 0.75)	330 (±14.4)	25000	1.48
T_2	25.5 (± 0.67)	6.72 (± 0.24)	0.75 (± 0.02)	0.58 (± 0.02)	73.2 (± 2.54)	28.8 (± 0.76)	1290 (± 5.0)	62500	3.22
T_3	18.5 (± 0.49)	6.79 (± 0.14)	0.71 (± 0.02)	0.47 (± 0.01)	71.6 (± 1.90)	31.5 (± 0.83)	1050 (±15.7)	52500	2.66
T_4	25.8 (± 0.26)	6.51 (± 0.17)	0.70 (± 0.01)	0.59 (± 0.03)	83.4 (± 4.59)	30.7 (± 0.31)	1275 (±22.1)	75000	3.78
T_5	23.6 (± 0.85)	7.65 (± 0.08)	0.75 (± 0.03)	0.92 (± 0.03)	108 (± 3.31)	34.5 (±1.24)	2105 (±18.3)	70000	3.07
T_6	23.0 (± 0.83)	7.65 (± 0.20)	0.83 (± 0.03)	0.59 (± 0.02)	87.0 (± 3.14)	29.2 (± 1.05)	2050 (±24.7)	70000	2.95
T_7	23.6 (± 0.85)	7.71 (± 0.28)	0.87 (± 0.03)	0.57 (± 0.02)	128 (± 4.62)	30.6 (± 1.10)	2405 (±26.3)	50000	2.96

** Data are presented as mean ± standard deviation.*
** indicates significant difference comparing with the control group ($p < 0.05$).*

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Table. 3. Impact of ZBNF practices and its impact on post-harvest soil characteristics

Treat-ments	pH	EC (d Sm^{-1})	Organic carbon (%)	Avail. N (kg ha^{-1})	Avail. P (kg ha^{-1})	Avail. K (kg ha^{-1})	Avail. Cu (mgkg^{-1})	Avail. Fe (mg kg^{-1})	Avail. Zn (mg kg^{-1})	Avail. Mn (mg kg^{-1})
T_1	6.10	0.90	0.43	92.4	20	98	38.4	12.8	24.2	86.6
T_2	5.50	0.78	0.65	134.4	40	151	33.0	16.2	23.2	113.3
T_3	7.42	1.30	0.85	151.2	50	135	39.1	12.6	25.7	128.0
T_4	6.40	0.62	0.51	117.6	30	228	29.1	82.1	21.6	129.7
T_5	6.54	1.04	0.68	140.0	30	173	27.4	10.5	21.6	133.7
T_6	5.80	0.66	0.45	123.2	40	144	33.7	14.5	26.4	96.5
T_7	5.70	0.84	0.36	129.0	30	162	36.2	64.4	27.4	135.5
SED	**0.04**	**0.02**	**0.65**	**0.30**	**0.54**	**0.75**	**0.41**	**0.31**	**0.17**	**0.48**
CD (0.05%)	**0.09**	**0.06**	**1.42**	**0.66**	**1.18**	**1.64**	**0.91**	**0.67**	**0.38**	**1.05**

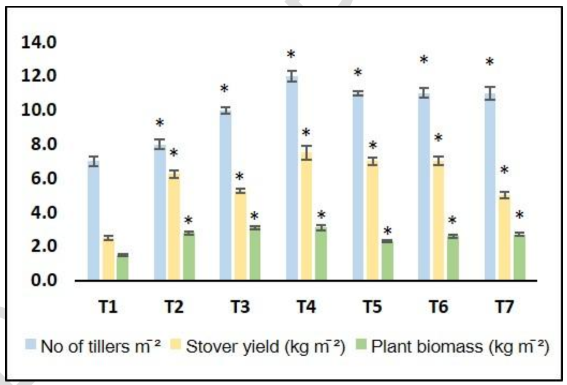

Fig. 1. Effect of ZBNF practices and its impact on yield of sorghum

In earlier studies under conventional farming system, cowpea showed high positive interactive effect in intercropping with sorghum in ratio of two sorghum rows alternated with one cowpea row, where there had been a marked increase in land equivalent ratio coupled with higher yield of sorghum (Oseni, 2010). In the present finding combination of ZBNF with cowpea resulted in a similar yield increase pattern in sorghum when compared to control. Ramamurthy *et al*. (2023) evaluated intercropping of two pulses namely cowpea and horse gram with Bt cotton as main crop and observed that in the sole cropping system comparatively lesser yield of cotton bolls was recorded than the intercropping with pulse crop.

Micronutrients varied among different treatments where the highest and lowest available copper was reported in ZBNF practices (T_3) and NPOF package (T_5) with 39.1 and 27.4 mg kg^{-1}. Available Fe showed the highest and lowest values in the treatments of natural farming practices and ZBNF practices (T_4) and NPOF package (T_5) with 82.1 and 10.5 mg kg^{-1}. Available Zn was reported to be higher in ICM (50 % organic + 50 % inorganic with need based *Neemastra, Agniastra, Brahmastra*(T_7) and lower in natural farming practices and ZBNF practices (T_4) and NPOF package (T_5) with 27.4 and 21.6 mg kg^{-1}. Available Mn was reported to be higher and lower in NPOF package (T_5) and control (T_1) with 133.7 and 86.6 mg kg^{-1}. The changes in the soil properties might be due to addition of organic compounds present in the inputs which resulted in the higher nutrient availability and microbial load in the soil. These results were reported by Santhosh *et al*. (2018). The enhanced root development as evidenced by dry matter production under mentioned treatments may have also boosted the soil nutritional status. The mineralization and solubilizing impact of soil microorganisms, particularly in the presence of CO_2 generated by the root, also increases available micro and macronutrients (Ramah, 2008).The results obtained in the present study is in line with the findings of Veeranna*et al*. (2023) who proved that the combined application of ~~*gnanajeevamirth*~~*Ghanajeevamrith* and *jeeva~~mirth~~mrith* in four equal splits registered higher pod yield of groundnut. Higher nutrient uptake (NPK) was recorded with the application of nutrients through recommended dose of FYM and fertilizers followed by the combined application of ~~*gnanajeevamirth*~~*Ghanajeevamrith* along with *jeeva~~mirth~~mrith* through four equal splits.

4. CONCLUSION

With respect to overall comparison of the grain yield in sorghum, significantly higher yield (2405 kg ha^{-1}) was recorded in Integrated crop management (ICM-II) (50 % organic manures + 50% inorganic with need based *Neemastra*, *Agniastra*, *Brahmastra* (T_7). However, in comparison of the sorghum yield with respect to cowpea intercropping, higher BCR of 3.78 was recorded in T_4 with grain yield of 1275 kg ha^{-1}. ZBNF treatment (*Bija~~mirth~~mrith* + *Jeeva~~mirth~~mrith* + *Whapasa* + *Acchadana* + ~~*Gnanajeevamirth*~~*Ghanajeevamrith* (T_2) obtained 23 percent of higher grain yield in the sorghum crop with BCR of 3.22 compared to ZBNF practices combined with cowpea intercropping (T_3). Natural agricultural practices and state-recommended organic procedures have higher BCR values due to the higher market price for organic produce. The social movement adopting ZBNF has a need of scientific support to understand the aim, scope and scientific validation through a scientific way of statistical research. Our findings from the first on-the-ground evaluation on the effects of sorghum intercropping with cowpea by zero budget natural farming practices on yield of sorghum, suggest that there is an assured initial yield impact when converting to ZBNF compared to organic or conventional systems.

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