Indian Journal of Weed Science **50**(4): 355–364, 2018

Print ISSN 0253-8040 Online ISSN 0974-8164

Weed dynamics in conservation agricultural systems as influenced by conservation tillage and nutrient management practices under rainfed finger millet

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Article information

DOI: 10.5958/0974-8164.2018.00076.X

Type of article: Research article

Received : 20 August 2018
Revised : 5 September 2018
Accepted : 7 November 2018

Key words

Tillage

Nutrient

Weed, Weed seed bank

Nutrient uptake

Yield

ABSTRACT

Weeds are major threats for loss of yield in any cropping system. Especially in conservation tillage systems, it is a basic necessary requirement to keep the weed population below their threshold levels to realize optimum grain yields. Managing weeds in conservation tillage systems are very essential to optimize crop production. Hence, to study the effect of conservation tillage practices on weed dynamics, soil weed seed bank and their distribution, a field experiment was conducted under rainfed finger millet (*Eleusine coracana* (L.) Gaertn.) on *Alfisols* for two consecutive seasons during 2014 and 2015 at All India Coordinated Research Project on Dryland Agriculture, University of Agricultural Sciences, GKVK, Bengaluru, India under split-plot design with three main plots (different tillages) and five sub-plots (different nutrient management). Conventional tillage has recorded significantly higher grain and straw yield of finger millet (3.04 and 4.69 t/ha, respectively) due to effective control of weeds as evidenced by lower total weed density and dry weight observed (13.7 no./m^2, 8.0 g/m^2 at 30 DAS and 23.9 no./m^2, 9.0 g/m^2 at 60 DAS) along with higher weed control efficiency (92.5-93.2% in 2014 and 93.3-93.8% in 2015) and lower weed index (7.6-10.3%) due to lower number of weed seeds observed during 2014 (12.3, 19.5 and 4.6/kg soil at 15, 30 and 60 days, respectively) and 2015 (11.3, 17.6 and 4.1/kg soil at 15, 30 and 60 days, respectively as compared to minimum tillage (2.60 and 4.03 t/ha, respectively). Whereas, zero tillage has recorded significantly lower grain and straw yield (2.09 and 3.24 t/ha, respectively) due to poor weed control as observed by higher soil weed seed bank. Among different nutrient management practices application of 100% recommended NPK + 7.5 t FYM/ha yielded significantly higher grain and straw yields (3.03 and 4.68 t/ha, respectively) over other nutrient management practices. Wherein, the soil weed seed bank was not significantly influenced by nutrient management practices and their interactions with the tillage.

INTRODUCTION

Conservation agriculture practices are gaining a lot of importance across the globe due to their various advantages over conventional agricultural practices. These conservation agricultural practices serve as an alternative strategy to sustain agricultural production due to the growing resource degradation problems, particularly under rainfed conditions. These rainfed systems are characterized by low and unstable yields, vulnerable to erratic rainfall, prone to frequent droughts amidst the declining natural resource base. Hence the conservation of soil, water and other natural resources is a crucial factor for achieving sustainable production in rainfed farming. Whereas, the weed menace is very high under conservation tillage systems such as minimum and zero tillages due to less intense tillage practices. This higher weed menace under less intense tillage practices is attributed to continuous deposition of weed seeds in the top soil layer due to no soil disturbance which eventually emerge as the congenial conditions prevail and compete with the crops. Managing weed population below the economic threshold level is the basic need to optimize the productivity in any cropping systems especially in conservation tillage systems.

The weed emergence is directly proportional to the number of viable weed seeds present in soil called as 'soil weed seed bank', which are reserves of viable seeds present on the surface and in the soil containing new seeds recently shed by weed plants as well as older seeds that have persisted in the soil for several years. Thus, the weed seed bank is an indicator of past and present weed populations in soil and is the main source of weeds in agricultural fields. Management of weeds in a particular area would require prior information on weed seed bank which really helps in designing weed management practices related to a particular micro-climate in an area. As tillage influences the vertical distribution of weed seeds in soil layer and weed diversity, no-till cropping systems leave most seeds in top 1.0 cm layer of the soil profile (Yenish *et al.* 1992). The differential distribution of seeds in the soil profile subsequently leads to change in weed population dynamics.

Finger millet (*Eleusine coracana* (L.) Gaertn.) belongs to family Poaceae (subfamily: Chloridoideae) widely grown as millet in the arid regions of Africa and Asia (India and Nepal). The most striking feature, which made finger millet an important dryland crop is, its resilience and ability to withstand adverse weather conditions when grown in soils having poor water holding capacity. It is a predominant food crop of the Southern part of Karnataka, mainly grown under rainfed conditions in *Alfisols* in India. Globally innovations of conservation agriculture-based crop management technologies are said to be more efficient, use fewer inputs, improve production and income, and address the emerging problems (Gupta and Seth 2007). An undeniable and expensive consequence of agricultural practices in the management of weeds in agricultural systems as the weeds are responsible for significant crop yield and financial losses in agricultural production in the order of 10 per cent per year worldwide (Oerke 2006). With these backgrounds, this study was conducted to study the weed dynamics, soil weed seed bank and their distribution as influenced by conservation tillage and nutrient management practices under rainfed finger millet (*Eleusine coracana* (L.) Gaertn.) on *Alfisols* at Eastern Dry Zone of Karnataka in India.

MATERIAL AND METHODS

A field experiment was carried out to study the weed dynamics, soil weed seed bank and their distribution on *Alfisols* as influenced by conservation tillage and nutrient management practices under rainfed finger millet (*Eleusine coracana* (L.) Gaertn.) in two consecutive seasons at *Kharif* 2014 and 2015 at All India Coordinated Research Project on Dryland Agriculture, University of Agricultural Sciences, Gandhi Krishi Vigyan Kendra, Bengaluru (India). The experimental site was located at the Eastern Dry Zone of Karnataka at a latitude of $12^0$58' N and longitude of $75^0$35' E at an altitude of 930 m above mean sea level. The soil type of the experimental site belongs to Vijayapura series and represents the typical lateritic area of Bengaluru plateau. These soils were classified as fine, kaolinitic, isohyperthermic, Typic Kandiustalf as per USDA classification. These soils were deep, yellowish red, lateritic, red sandy clay loam with good drainage and were derived from granite-gneiss under subtropical semi-arid climate. The texture of soil was red sandy clay loam (33.2% coarse sand, 36.4% fine sand, 7.00% silt and 23.0% clay). The soils were acidic, lower in organic carbon, available nitrogen, potassium and medium in available phosphorous.

The experiment was conducted under split-plot design with three tillage treatments as main plots, *viz.* Conventional tillage [2 ploughings + 1 harrowing + 2 inter cultivation at 25 and 50 days after sowing (DAS)] with drill sown finger millet, minimum tillage (1 ploughing + 1 harrowing + application of pre-emergence herbicide - isoproturon 75 WP at 565 g/ha) - drill sown finger millet and zero tillage (glyphosate 41 SL at 10 ml/l at 15 days before transplanting) with transplanted finger millet at 25 DAS and five nutrient management treatments as sub-plots, *viz.* 100 % recommended NPK (50:40:25 kg NPK/ha), 100% recommended NPK + 7.5 t FYM/ha, horsegram residue mulch + 100% recommended NPK, horsegram residue mulch + 50% recommended NPK + 25% N through FYM + *Azotobacter* seed treatment and horsegram residue mulch + fertilizers based on soil test results and are replicated thrice. In both the seasons, the soil was found low in available N, K, and medium in available P, hence 130% N, K and 100% recommended P were applied in N_5 treatment.

The pre-emergence herbicide isoproturon 75 WP at 565 g/ha was applied in minimum tillage plots two DAS using knapsack sprayer with WFN 78 nozzle with a spray volume of 750 l/ha. The post-emergence herbicide glyphosate was applied in the zero tillage plots at 15 days before transplanting *i.e.*, glyphosate 41 SL at 10 ml/l using knapsack sprayer with WFN 40 nozzle with a spray volume of 500 l/ha at the active green stage of weeds. The ploughing and harrowing operations were done using tractor-drawn cultivator and disc harrow, respectively and inter cultivations were done using blade hoe at 25 and 50 DAS using bullock pair as per the treatments in respective plots. The finger millet variety '*GPU-28'* was sown/transplanted at a spacing of 30 x 10 cm with a seed rate of 10 kg/ha on 9th August, during 2014 and 10th August during 2015. On the same date of sowing of finger millet in the main field, the sowing of seeds in the nursery was also done and seedlings were transplanted at 25 DAS to the main field after giving light irrigation (5 mm) to overcome the transplanting shock. The fertilizer sources used were urea, DAP and MOP. 50% of recommended nitrogen and entire phosphorus and potassium were given as basal dose at the time of sowing and remaining 50% of nitrogen was applied as a top dress at 30 DAS. The horsegram (*Dolichos biflorus* L.) seeds (variety '*PHG-9*') were broadcasted at 50 kg/ha in the first fortnight of May with pre-monsoon rains in respective treatment plots for mulching and harvested at 60 DAS and was mulched in between complete established finger millet crop rows (During the first year of experiment *i. e.,* 2014, the average quantity of 970 kg/ha dry horsegram biomass was harvested and was applied uniformly in all mulched plots. During 2015, the amount of horsegram biomass generated from individual treatment plots was applied to their respective plots *i. e.,* horsegram residue mulch + 100 % recommended NPK – 1038 kg/ha, horsegram residue mulch + 50% recommended NPK + 25% N through FYM + *Azotobacter* seed treatment – 948 kg/ha, horsegram residue mulch + fertilizers based on soil test results – 1159 kg/ha, and the composition of horsegram biomass was 0.50% N, 0.15% P and 0.39% K. The seeds were treated with *Azotobacter* nitrogen-fixing biofertilizer and while transplanting, the root dipping of seedlings was done as per the treatments. The calculated amount of farm yard manure was incorporated into the soil fifteen days before sowing. The FYM on N basis was applied by considering the N content of FYM *i.e.,* 0.50% (The composition of FYM was 0.50% N, 0.21% P and 0.50% K). In places where the finger millet seeds were failed to germinate and excess populations, the gap filling and thinning were done, respectively at 15 DAS to maintain optimum plant population and intra row spacing.

The total amount of rainfall received was more than normal in both the years with 994.5 mm during 2014 and 1070.5 mm during 2015. The crop growth period was from May to December in both the seasons (horsegram-finger millet). The previous crop grown at the experimental site was finger millet + pigeonpea intercropping during *Kharif* 2013 and left fallow during *Rabi* and Summer. During the second season of the experiment, due to the long dry spell, protective irrigation (10.2 mm) was given on 27-10-2015. For weed observations from the field, a quadrant of 0.5 × 0.5 m was selected in each treatment at random for recording weed count at two spots per plot and expressed as number/m^2 and averaged over two random spots per plot at 30 and 60 DAS. Out of two random spots per plot, one of the sampled spot was selected for recording weed dry weight and were dried in hot air oven at 65ºC, till constant dry weight was recorded. The dry weight of weeds was expressed as g/m^2.

For the weed seed bank experiment, the experiment was conducted using factorial CRD design with 45 treatment combinations (3 main plot tillage treatment x 5 nutrient management practices x 3 soil depths) and three replications. The weed seed distribution in the soils of the experimental site was studied at different depths through plastic tray culture experiments in the shade house. Soil samples were collected from the experimental site after harvest of finger millet at three different depths *i.e.,* 0-10, 10-20 and 20-30 cm and dried under shade. One kg of soil from each depth was weighed and kept in the plastic pots containing holes at bottom side in all the four corners to study the emerged weeds present in the soil. The pots were watered manually as and when needed to maintain adequate moisture. After germination, the weed seedlings were identified, counted and removed and again soil was thoroughly stirred and watered regularly for another flush of weeds. The cycle of operation was repeated till all the weed seeds were exhausted. Later the original values of weed density, dry weight and soil weed seed bank were subjected to suitable transformations (square root or logarithmic) depending on the variation in the data and subjected to statistical analysis.

The weed control efficiency was worked out using the formula as suggested by Mani *et al.* (1973) and weed index was worked out by using the formula given by Gill and Kumar (1969). The crop was harvested on 12-12-2014 during the first season and on 03-12-2015 during the second season of the experiment. The grain and straw weight were recorded and were converted into kg/ha.

The nitrogen content in weed samples was estimated by Micro Kjeldhal method (Jackson 1967). Whereas, the phosphorus and potassium were digested in di-acid mixture (900 ml conc. HNO_3 + 400 ml of per chloric acid) as described by Piper (1966) and the phosphorus content of the di-acid digested grain and straw samples was determined by Vanado molybdo phosphoric yellow colour method (Jackson 1967) and the potassium content in weed samples was determined by flame photometer method as described by Jackson (1967) and expressed in percentage on dry weight basis. The percentage concentration of these nutrients was multiplied with biomass of weeds to get the total nutrient uptake by weeds (kg/ha).

The experimental data on weed data, nutrient uptake, the yield of finger millet *etc.* were subjected to Fisher's method of "Analysis of variance" (ANOVA) as outlined by Gomez and Gomez (1984). The pooled analysis was also done using two season's data. The emphasis was given to present the results of the pooled data instead of the individual season/year wise as a similar trend was observed in both the seasons/ years of the field experiment. Whenever F-test was significant for comparison amongst the treatment means, an appropriate value of least significant differences (LSD) was worked out. Otherwise against LSD values, abbreviation NS (Non-Significant) was indicated. All the data were analyzed and the results were presented and discussed at a probability level of 0.05 percent and correlation study was done as given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Weed flora

The different weed species found during experimental period in finger millet crop up to initial 60 DAS were *Cyperus rotundus* (L.) among sedges, *Digitaria marginata* (L.), *Cynodon dactylon* (L.), *Eleusine indica* (L.) among grasses and *Borreria hispida* (L.), *Portulaca oleracea* (L.), *Mimosa pudica* (L.), *Phyllanthus niruri* (L.), *Euphorbia geniculata* (O.), *Commelina benghalensis* (L.), *Chenopodium album* (L.) among broad-leaved weeds. Among sedges, *Cyperus rotundus* (L.) and among broad-leaved weeds, *Borreria hispida* (L.) were dominant. Among grasses, all the weeds were more or less equally found dominant. At later stages, other weeds species found were *Cyperus iria* (L.), *Dactyloctenium aegyptium* (L.), *Chloris barbata* (Sw.), *Panicum repens* (L.), *Ageratum conyzoides* (Orteg.), *Euphorbia geniculata* (O.), *Cleome monophylla* (L.), *Achyranthus aspera* (L.), *Amaranthus viridis* (Hook. F.), and *Acanthospermum hispidum* (DC.). The emergence of different weed species was attributed to soil weed seed bank, difference in tillage intensity, earlier cropping system, weather parameters, congeniality of soil environment *etc*. Changing tillage regimes changes the disturbance frequency of the farm field and crop management strongly influences weed communities and a change in tillage is expected to have a pronounced effect on the weed community and results in a diversity of weed species (Boscutti *et al.* 2015 and Nichols *et al.* 2015).

Weed density and dry weight

The density of weeds was significantly influenced by the different tillage practices in finger millet (**Table 1**). Among different tillage practices, conventional tillage [(2 ploughings + 1 harrowing + 2 inter cultivations) – sowing] recorded significantly lower density and dry weight of weeds at 30 DAS (13.7 no./m^2 and 8.0 g/m^2, respectively) and 60 DAS (23.9 no./m^2 and 9.0 g/m^2, respectively) as compared to minimum tillage [(1 ploughing + 1 harrowing + pre-emergence herbicide spray) - sowing)] at 30 DAS (40.0 no./m^2 and 30.2 g/m^2, respectively) and 60 DAS (73.2 no./m^2 and 22.2 g/m^2, respectively). While significantly higher weed density and dry weight were observed under zero tillage **(**blanket herbicide spray) **-** transplanting at 30 DAS (97.4 no./m^2 and 64.8 g/m^2, respectively) and 60 DAS (199.0 no./m^2 and 67.6 g/m^2, respectively). There was no significant difference observed among different nutrient management practices and their interactions with the tillage at different crop growth stages of finger millet for density as well as the dry weight of weeds.

The lower weed density and dry weight in conventional tillage were because of inversion of soil by ploughing and subsequent inter cultivation at 25 and 50 DAS which removed germinated weeds and helped in physical suppression of weeds. Nichols *et al.* (2015) quoted that tillage kill live weeds before they reproduce, thus preventing seed production and it is a useful tool for controlling established weed population, curtailing the weed seed bank and weed intensities. Minimum tillage has recorded comparatively better weed control next to conventional tillage because of translocation of soil-applied pre-emergence isoproturon 75 WP herbicide at 565 g/ha into the foliage which turns green leaves into light green coloured leaves followed by burning of leaf tips, chlorosis, growth retardation and eventually death of plants due to the interference of isoproturon with the reducing side of PS-II (Radosevich *et al.* 1979). Whereas, significantly higher weed density and dry weight under zero tillage were due to the deposition of weed seeds in the top layer itself due to no soil inversion and soil disturbance and more number of weeds from the previous seasons. These seeds remain viable and germinate whenever they get congenial conditions. Romaneckas *et al.* (2009) witnessed more weed infestation in zero tillage than conventional and minimum tillage systems. Subbulakshmi *et al.* (2009) reported that zero tillage resulted in the deposition of more seeds and propagules of predominant annual and perennial weeds near the soil surface.

Table 1. Total weed density and dry weight in finger millet at 30 and 60 DAS as influenced by tillage and nutrient management practices

Treatment	Weed density (no./m^2)						Weed dry weight (g/m^2)					
	30 DAS#			60 DAS#			30 DAS#			60 DAS#		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
Tillage practice												
Conventional tillage- Sowing	1.06 (13.2)	1.21 (14.1)	1.19 (13.7)	1.22 (21.3)	1.45 (26.5)	1.40 (23.9)	0.92 (8.2)	0.98 (7.7)	0.99 (8.0)	1.00 (9.2)	1.03 (8.79)	1.04 (9.02)
Minimum tillage- Sowing	1.65 (43.3)	1.58 (36.8)	1.62 (40.0)	1.84 (69.8)	1.89 (76.7)	1.87 (73.2)	1.50 (30.4)	1.49 (30.1)	1.49 (30.2)	1.35 (22.3)	1.37 (22.2)	1.38 (22.2)
Zero tillage-Transplanting	1.95 (93.7)	2.01 (101.2)	1.99 (97.4)	2.24 (185.7)	2.31 (212.3)	2.28 (199.0)	1.78 (63.4)	1.82 (66.1)	1.81 (64.8)	1.76 (57.5)	1.89 (77.7)	1.82 (67.6)
LSD (p=0.05)	0.28	0.24	0.25	0.32	0.34	0.33	0.24	0.21	0.05	0.15	0.11	0.12
Nutrient management practice												
100 % recommended NPK (50:40:25 kg NPK/ha)	1.60 (51.7)	1.64 (51.9)	1.61 (52.4)	1.82 (94.7)	1.89 (108.8)	1.87 (105.3)	1.44 (34.5)	1.45 (36.1)	1.45 (37.5)	1.42 (30.6)	1.44 (38.2)	1.43 (36.0)
100% recommended NPK + 7.5 t FYM/ha	1.71 (60.0)	1.63 (53.7)	1.64 (54.4)	1.94 (109.3)	1.94 (114.2)	1.92 (107.4)	1.54 (40.6)	1.47 (38.8)	1.49 (38.7)	1.48 (35.1)	1.48 (39.5)	1.47 (36.6)
Horsegram residue mulch + 100 % recommended NPK	1.45 (41.7)	1.58 (48.5)	1.57 (47.4)	1.65 (77.3)	1.85 (96.3)	1.80 (87.4)	1.32 (28.6)	1.40 (31.7)	1.39 (30.6)	1.29 (24.8)	1.40 (33.2)	1.37 (29.6)
Horsegram residue mulch + 50 % recommended NPK + 25 % N through FYM + *Azotobacter* seed treatment	1.54 (48.9)	1.59 (49.8)	1.59 (49.2)	1.76 (90.5)	1.87 (99.1)	1.83 (91.4)	1.39 (33.4)	1.42 (33.0)	1.42 (32.6)	1.37 (29.8)	1.42 (34.6)	1.40 (31.4)
Horsegram residue mulch + Fertilizers based on soil test results	1.46 (48.0)	1.59 (49.7)	1.58 (48.5)	1.67 (89.4)	1.87 (107.3)	1.85 (100.0)	1.32 (32.9)	1.41 (33.7)	1.41 (32.2)	1.28 (28.0)	1.41 (35.7)	1.39 (31.3)
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

DAS-Days after sowing, # $\sqrt{x+2}$ transformation, Figures in parentheses indicate original values, DAS-Days after sowing, NS-Non significant

Wherein, there was no significant difference between sub-plot nutrient management due to the absence of weed management procedures under sub-plots.

Weed control efficiency and weed index

The crop yield is directly proportional to weed control efficiency (WCE) and inversely related to weed index (WI) in any crop. Conventional tillage in finger millet has attained higher WCE at 30 DAS (92.5 to 93.2%) and 60 DAS (93.3 to 93.8%) as compared to minimum and zero tillage **(Table 2)**. And the lowest weed index was observed under conventional tillage (10.26 and 7.56% in 2014 and 2015, respectively) as compared to that of minimum tillage (22.70 and 21.27% in 2014 and 2015, respectively) and zero tillage (35.49 and 39.82% in 2014 and 2015, respectively). The WI indicates the percent yield loss caused due to the presence of weeds than weed-free conditions. Hence, the lower weed index and higher weed control efficiency in conventional tillage were attributed to a lower loss in crop yields due to lower weed competition as indicated by lower total weed density and dry weight (**Table 1**) at 30 and 60 DAS as compared to minimum and zero tillage. The WCE was increased from 2014 to 2015 in conventional tillage and minimum tillage due to their reduction in total weed dry weight from 2014 to 2015. Whereas in zero tillage, the WCE was lowered from 2014 to 2015 due to increased total weed dry weight due to increased soil weed seed bank from 2014 to 2015. Subbulakshmi *et al*. (2009) who recorded a higher weed index under zero tillage in maize-sunflower cropping system due to the higher weed density and dry weight in zero tillage.

Nutrient uptake by weeds

Weeds are the major competitors for the absorption of nutrients in the crop fields. Therefore appropriate measures have to be taken to manage the weeds to grab satisfactory crop yields. Among different tillage practices, conventional tillage has shown significantly lower uptake of nutrients (7.9, 6.0 and 12.8 kg N, P and K/ha, respectively) by weeds as compared to minimum tillage (14.8, 11.6 and 24.1 kg N, P and K/ha, respectively) and zero tillage (22.2, 16.7 and 34.8 kg N, P and K/ha, respectively). Whereas, the various nutrient management practices and their interactions with tillage were not significantly different for nutrient uptake by weeds **(Table 3)**. The lowest uptake of N, P and K by weeds in conventional tillage was an indication of lower weed dry weight at harvest due to effective weed control as indicated by lowest weed density. As the nutrient uptake by weeds and grain yields are negatively correlated (-0.781, -0.778 and -0.778 for N, P and K uptake by weeds with the grain yield) (**Table 4**), the lower nutrient uptake by weeds in conventional tillage has paved the way for higher nutrient uptake by crop, leading to higher grain yield.

Table 2. Weed control efficiency at different crop growth stages and weed index in finger millet as influenced by different tillage practices

Treatment	Weed control efficiency (%)				Weed index (%)	
	30 DAS		60 DAS			
	2014	2015	2014	2015	2014	2015
Tillage practice						
Conventional tillage- sowing	92.5	93.2	93.3	93.8	10.26	7.56
Minimum tillage- sowing	72.5	73.1	83.8	84.3	22.70	21.27
Zero tillage-transplanting	42.5	41.0	58.2	45.0	35.49	39.82

DAS-Days after sowing, The data on total weed dry weight in control (110.3 and 137.6 g/m^2 at 30 DAS and 60 DAS for 2014 and 112.1 and 141.5 g/m^2 at 30 DAS and 60 DAS, for 2015 for calculating WCE were taken from additionally maintained plots in the experimental area with normal package of practices. The data on grain yields under weed free conditions (3568 kg/ha for 2014 and 3115 kg/ha for 2015) for calculating WI were taken from additionally maintained plots in the experimental area.

Whereas in zero tillage, the higher nutrient uptake by weeds was attributed to their higher weed biomass. These findings are supported by Monsefi *et al.* (2016) who reported the highest uptake of N, P and K by weeds in zero tillage-raised bed system as compared to the conventional tillage-raised-bed system.

Yield of finger millet

The grain and straw yield of finger millet was significantly influenced by different conservation tillage and nutrient management practices. Conventional tillage has recorded significantly higher grain and straw yield of finger millet (3.04 and 4.69 t/ha, respectively) which is evidenced by lower weed index (10.26 and 7.56% in 2014 and 2015, respectively) as compared to minimum tillage (2.60 and 4.03 t/ha, respectively) **(Table 3)**. Whereas, zero tillage has recorded significantly lower grain and straw yield (2.09 and 3.24 t/ha, respectively). Among different nutrient management practices, application of 100 % recommended NPK + 7.5 t FYM/ha has realized significantly higher grain and straw yield of finger millet (3.03 and 4.68 t/ha, respectively) followed by horsegram residue mulch + fertilizers based on soil test results (2.70 and 4.17 t/ha, respectively) which was found on par with horsegram residue mulch + 100% recommended NPK (2.61 t/ha and 4.03 t/ha, respectively) as compared to 100% recommended NPK alone (2.32 and 3.58 t/ha, respectively). Wherein, significantly lower grain and straw yield were observed in horsegram residue mulch + 50% recommended NPK + 25% N through FYM + *Azotobacter* seed treatment (2.24 and 3.45 t/ha, respectively). The higher grain and straw yield of finger millet in conventional tillage was attributed to significantly lower total weed density and dry weight at 30 and 60 DAS due to effective control of weeds **(Table 1)** with tillage and inter cultivation. The lower grain yield in zero tillage was due to higher weed competition which was

Table 3. Nutrient uptake by weeds at harvest and yield of finger millet as influenced by tillage and nutrient management practices

Treatment	Nitrogen (kg/ha)			Phosphorus (kg P/ha)			Potassium (kg K/ha)			Grain yield (t/ha)			Straw yield (t/ha)		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
Tillage practice															
Conventional tillage- Sowing	8.0	7.8	7.9	6.3	5.7	6.0	13.2	12.5	12.8	3.20	2.88	3.04	4.95	4.42	4.69
Minimum tillage- Sowing	14.9	14.7	14.8	11.7	11.4	11.6	24.4	23.9	24.1	2.76	2.45	2.60	4.29	3.76	4.03
Zero tillage-Transplanting	22.0	22.5	22.2	16.4	16.9	16.7	34.5	35.1	34.8	2.30	1.87	2.09	3.61	2.87	3.24
LSD (p=0.05)	1.6	1.5	0.9	1.3	1.1	0.7	2.7	2.4	1.5	0.30	0.31	0.18	0.54	0.48	0.30
Nutrient management practice															
100 % recommended NPK (50:40:25 kg NPK/ha)	15.2	15.4	15.3	11.6	11.7	11.7	24.3	24.5	24.4	2.48	2.16	2.32	3.85	3.31	3.58
100 % recommended NPK + 7.5 t FYM/ha	15.6	15.6	15.6	12.0	11.8	11.9	25.1	24.7	24.9	3.25	2.81	3.03	5.06	4.31	4.68
Horsegram residue mulch + 100 % recommended NPK	14.5	14.5	14.5	11.1	10.9	11.0	23.2	23.0	23.1	2.79	2.42	2.61	4.35	3.72	4.03
Horsegram residue mulch + 50 % recommended NPK + 25 % N through FYM + *Azotobacter* seed treatment	15.0	14.9	15.0	11.5	11.3	11.4	24.0	23.8	23.9	2.37	2.10	2.24	3.68	3.23	3.45
Horsegram residue mulch + Fertilizers based on soil test results	14.6	14.6	14.6	11.2	11.0	11.1	23.5	23.2	23.3	2.88	2.51	2.70	4.48	3.86	4.17
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.19	0.25	0.15	0.30	0.38	0.24

Note: LSD-Least Significant difference, NS-Non significant clearly expressed by lower WCE (42.5 and 41.0% during 2014 and 2015 at 30 DAS and 58.2 and 45.0% during 2014 and 2015 at 60 DAS, respectively) and higher weed index (35.49 and 39.82% in 2014 and 2015, respectively) (**Table 2**). Due to increased weed density and dry weight in zero tillage, there was increased nutrient uptake by weeds (**Table 3**) at harvest which showed the greater magnitude of weeds competition on crops. This magnitude of weed competition in terms of nutrient uptake by weeds on finger millet yield was again also revealed through regression equations (**Table 4**). These regression equations demonstrated that each one kg increase in uptake of N, P and K by weeds will reduce the finger millet grain yields by 64.90, 86.89 and 42.09 kg grains/ha because of a negative correlation between nutrient uptake by weeds and grain yield of finger millet.

This decrease in grain yield with increase in weed density and dry weight in zero tillage was strongly depicted by significantly negative correlation coefficient (**Table 4**) between yield and total weed density at 30 and 60 DAS (-0.765 and -0.747, respectively) as well as between yield and total weed dry weight at 30 and 60 DAS (-0.760 and -0.744, respectively). Further the regression equations emphasized that, increase in total weed density by 1/m^2 at 30 DAS and 60 DAS as well as increase in total weed dry weight by one g/m^2 at 30 DAS and 60 DAS will cause decrease in grain yield of finger millet by 10.67, 4.92, 15.71 and 14.39 kg/ha. These results are in accordance with Guan *et al.* (2014) and Bilalis *et al.* (2011) who quoted that zero tillage in wheat and summer maize have registered lower grain yield due to poor growth, yield attributes and poor root growth due to increased soil penetration resistance, bulk density and weed growth.

The higher yield attributes gained under 100% recommended NPK + 7.5 t FYM/ha has come from improved growth attributes because of improved nutrient availability as a consequence of sufficient and integrated nutrient supply from both inorganic and organic sources. This application of FYM has led to improvement in soil physico-chemical properties which ultimately resulted in favouring of crop growth for higher yield. Whereas, the application of horsegram residue mulch + 50% recommended NPK + 25% N through FYM + *Azotobacter* seed treatment has recorded lower yield due to poor nutrient supply.

Soil weed seed bank

The tillage practices have the profound influence on the distribution of weed seeds and seed bank size in the soil profile. In zero tillage, seeds infiltrate the soil via very slow processes (cracks, fauna, freeze-dry cycles), resulting in an accumulation of weed seeds (60–90%) in the top 5 cm of the soil (Yenish *et al.* 1992). Thus, tillage induces changes in seed distribution therefore indirectly affect the germination and seedling establishment. The weed seed bank is defined as the mature seeds that exist in the soil. At any given time, the soil seed bank contains viable weed seeds produced in several previous years (the seed bank). These seeds (consisting of different ages) will either be able to germinate when the conditions are favourable (suitable temperature, adequate water and enough oxygen) or be dormant. Among different tillage practices, conventional tillage has exhibited a lower number of grasses, sedges and broadleaf weeds (2.70 to 5.78/kg soil at 15 days, 4.54 to 8.76/kg soil at 30 days and 1.15 to 1.79/kg soil at 60 days). This was followed by minimum tillage (6.28 to 16.51/kg soil at 15 days, 9.94 to 20.57/kg soil at 30 days and 3.27 to 4.15/kg soil at 60 days) and

Table 4. Correlation and regression equations for weed density, weed dry weight, nutrient uptake by weeds and total weed seeds with grain yield of finger millet as influenced by tillage and nutrient management practices

Dependent variable (Y)	Independent variable (x)	Correlation coefficient (r)	Regression equation	R^2
Grain yield (kg/ha)	TWD at 30 DAS (no./m^2)	-0.765	Y=3116.14-10.67x	0.585
	TWD at 60 DAS (no./m^2)	-0.747	Y=3064.159-4.92x	0.559
	TWDW at 30 DAS (g/m^2)	-0.760	Y=3117.61-15.71x	0.578
	TWDW at 60 DAS (g/m^2)	-0.744	Y=3052.49-14.39x	0.554
	Total N uptake by weeds (kg/ha)	-0.781	Y=3550.51-64.90x	0.610
	Total P uptake by weeds (kg/ha)	-0.778	Y=3571.34-86.89x	0.606
	Total K uptake by weeds (kg/ha)	-0.778	Y=3585.57-42.09x	0.606
		2014		
	TWS at 15 DAS	-0.729	Y=3529.16-25.62x	0.531
	TWS at 30 DAS	-0.726	Y=3593.86-19.55x	0.527
	TWS at 60 DAS	-0.727	Y=3387.97-50.92x	0.528
		2015		
	TWS at 15 DAS	-0.829	Y=3167.85-24.03x	0.687
	TWS at 30 DAS	-0.825	Y=3241.34-19.19x	0.681
	TWS at 60 DAS	-0.828	Y=3075.182-54.92x	0.686

Note: TWD- Total weed density, TWDW- Total weed dry weight. TWS-Total weed seeds zero tillage (12.02 to 21.43/kg soil at 15 days, 18.66 to 25.25/soil at 30 days and 6.08 to 8.49/kg soil at 60 days) during 2014.

Among different depths, the top 0-10 cm soil depth has witnessed the significantly higher number of weeds (12.19 to 24.05/kg soil at 15 days, 16.44 to 29.74/kg soil at 30 days and 5.51 to 8.12/kg soil at 60 days). It was followed by 10-20 cm depth and 20-30 cm depth during 2014 **(Table 5 and 6)**. Whereas, the different nutrient management practices, the interaction of tillage and nutrient management practices, nutrient management practices and depths were found non-significant for different categories of weeds at 15, 30 and 60 days during 2014. But, the interactions of tillage and depth were significantly different for different categories of weeds. Among different interactions, 0-10 cm soil depth samples of zero tillage practice has demonstrated significantly higher number of weeds (51.41 to 36.73/kg soil at 15 days, 28.63 to 43.16/kg soil at 30 days and 9.67 to 14.56/kg soil at 60 days) followed by other interactions and significantly lowest number of weeds were observed under 20-30 cm in conventional tillage (0.33 to 1.51/kg soil at 15 days,

Table 5. Weed no./kg of soil at different days as influenced by tillage and nutrient management practices during 2014

Treatments	At 15 days				At 30 days				At 60 days			
	Sedge*	Grasses*	BLW*	Total#	Sedge*	Grasses*	BLW*	Total#	Sedge*	Grasses*	BLW*	Total*
Tillage practice												
T_1	1.86 (2.7)	2.12 (3.8)	2.52 (5.8)	1.08 (12.3)	2.30 (4.5)	2.55 (5.9)	3.02 (8.8)	1.26 (19.5)	1.44 (1.1)	1.56 (1.6)	1.62 (1.8)	2.20 (4.6)
T_2	2.62 (6.3)	3.11 (9.1)	4.07 (16.5)	1.48 (31.9)	3.26 (9.9)	3.85 (14.6)	4.52 (20.6)	1.63 (45.1)	2.03 (3.3)	2.10 (3.7)	2.21 (4.1)	3.37 (11.1)
T_3	3.50 (12.0)	3.66 (13.1)	4.61 (21.4)	1.64 (46.5)	4.37 (18.7)	4.51 (20.3)	4.99 (25.2)	1.78 (64.2)	2.62 (6.1)	2.77 (7.1)	3.01 (8.5)	4.64 (21.7)
LSD (p=0.05)	0.06	0.06	0.08	0.02	0.07	0.08	0.09	0.02	0.04	0.05	0.05	0.10
Nutrient management practice												
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Depths (C)												
D_1	3.49 (12.2)	3.77 (14.1)	4.83 (24.0)	1.65 (50.4)	4.02 (16.4)	4.63 (21.9)	5.40 (29.7)	1.79 (68.0)	2.46 (5.5)	2.77 (7.2)	2.91 (8.1)	4.47 (20.9)
D_2	2.52 (5.5)	2.88 (7.4)	3.57 (12.0)	1.41 (24.9)	3.15 (9.2)	3.52 (11.6)	4.02 (15.3)	1.57 (36.4)	1.94 (2.8)	2.06 (3.3)	2.20 (3.9)	3.28 (10.1)
D_3	1.96 (3.3)	2.25 (4.5)	2.79 (7.6)	1.13 (15.5)	2.76 (7.5)	2.76 (7.4)	3.11 (9.5)	1.32 (24.4)	1.69 (2.2)	1.60 (1.8)	1.73 (2.4)	2.45 (6.4)
LSD (p=0.05)	0.06	0.06	0.08	0.02	0.07	0.08	0.09	0.02	0.04	0.05	0.05	0.10
Tillage (T) × Nutrient management practice												
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Tillage (T) × Depths (C)												
T_1D_1	2.29 (4.2)	2.54 (5.4)	3.06 (8.4)	1.30 (18.1)	2.63 (5.9)	3.05 (8.3)	3.67 (12.5)	1.46 (26.7)	1.64 (1.7)	1.90 (2.6)	1.94 (2.8)	2.84 (7.0)
T_1D_2	2.12 (3.5)	2.47 (5.1)	2.91 (7.4)	1.26 (16.1)	2.66 (6.1)	2.97 (7.8)	3.49 (11.2)	1.43 (25.9)	1.65 (1.7)	1.81 (2.3)	1.88 (2.5)	2.75 (6.6)
T_1D_3	1.15 (0.3)	1.36 (0.8)	1.58 (1.5)	0.67 (2.7)	1.62 (1.6)	1.63 (1.6)	1.90 (2.6)	0.90 (5.9)	1.01 (0.0)	1.22 (0.5)	1.30 (0.7)	1.49 (1.2)
T_2D_1	3.45 (10.9)	3.97 (14.8)	5.29 (27.0)	1.74 (52.8)	3.97 (14.7)	4.93 (23.3)	5.87 (33.6)	1.87 (71.6)	2.48 (5.1)	2.73 (6.5)	2.83 (7.0)	4.43 (18.7)
T_2D_2	2.48 (5.2)	3.00 (8.0)	3.89 (14.2)	1.46 (27.4)	3.10 (8.8)	3.72 (13.0)	4.32 (17.7)	1.61 (39.4)	1.94 (2.8)	2.01 (3.0)	2.14 (3.6)	3.20 (9.5)
T_2D_3	1.92 (2.7)	2.35 (4.6)	3.03 (8.3)	1.24 (15.6)	2.70 (6.3)	2.91 (7.5)	3.36 (10.4)	1.42 (24.2)	1.69 (1.8)	1.56 (1.5)	1.67 (1.8)	2.47 (5.1)
T_3D_1	4.73 (51.4)	4.80 (22.01)	6.14 (36.7)	1.91 (80.2)	5.44 (28.6)	5.91 (34.0)	6.65 (43.2)	2.03 (105.8)	3.27 (9.7)	3.69 (12.6)	3.95 (14.6)	6.15 (36.9)
T_3D_2	2.96 (7.7)	3.15 (8.9)	3.93 (14.4)	1.52 (31.1)	3.70 (12.7)	3.88 (14.1)	4.25 (17.1)	1.66 (43.8)	2.22 (3.9)	2.36 (4.6)	2.59 (5.7)	3.90 (14.2)
T_3D_3	2.81 (6.9)	3.03 (8.2)	3.76 (13.1)	1.48 (28.3)	3.96 (14.7)	3.74 (13.0)	4.07 (15.5)	1.65 (43.2)	2.37 (4.6)	2.26 (4.1)	2.49 (5.2)	3.87 (13.9)
LSD (p=0.05)	0.10	0.11	0.14	0.03	0.12	0.13	0.15	0.04	0.08	0.08	0.08	0.17

T_1: Conventional tillage - Sowing, T_2: Minimum tillage - Sowing, T_3: Zero tillage-Transplanting, N_1: 100% recommended NPK (50:40:25 kg NPK/ha), N_2:100% recommended NPK + 7.5 t FYM/ha N_3:Horsegram residue mulch + 100% recommended NPK, N_4:Horsegram residue mulch + 50% recommended NPK + 25% N through FYM + *Azotobacter* seed treatment, N_5: Horsegram residue mulch + Fertilizers based on soil test results, D_1 - 0-10 cm, D_2 - 10-20 cm, D_3 - 20-30 cm. BLW-Broad leaved weeds, * - sqrt(x+1) transformation, # - log(x+2) transformation, Figures in parentheses indicate original values, LSD-Least Significant difference, NS-Non significant.

1.63 to 2.62/kg soil at 30 days and 0.02 to 0.70/kg soil at 60 days) during 2014.

The similar trend of soil weed seed bank **(Table 6)** at 15, 30 and 60 days were also observed during 2015. Lower weed seed number in conventional tillage was attributed to soil pulverization, removal of emerged weeds by follow up inter cultivation at 25 and 50 DAS which helped to lower the soil seed bank by avoiding further development and flowering of weeds. Nichols *et al*. (2015) stated that tillage is a mechanical method of weed control that can kill live weeds before they reproduce, thus preventing seed production and it is a useful tool for controlling established weed populations, curtailing the weed seed bank and weed intensities. Significantly higher soil weed seed bank under zero tillage was a result of addition and deposition of more number of weed seeds in the top soil layer due to no soil inversion, soil disturbance, no management actions on weeds after their emergence in the cropping season and increased deposition of weed seeds as a result of flowering of weeds from previous seasons. These weed seeds will germinate and emerge in the next season and so the cycle continues with an increase in soil weed seed

Table 6. Weed no./kg of soil at different days as influenced by tillage and nutrient management practices during 2015

Treatment	At 15 days				At 30 days				At 60 days			
	Sedge*	Grasses*	BLW*	Total#	Sedge*	Grasses*	BLW*	Total#	Sedge*	Grasses*	BLW*	Total*
Tillage practices (T)												
T_1	1.78 (2.4)	2.03 (3.4)	2.47 (5.5)	1.05 (11.3)	2.21 (4.1)	2.40 (5.1)	2.97 (8.4)	1.23 (17.6)	1.37 (1.0)	1.51 (1.4)	1.57 (1.6)	2.08 (4.1)
T_2	2.59 (6.1)	3.08 (8.9)	4.06 (16.4)	1.47 (31.5)	3.23 (9.7)	3.78 (14.1)	4.50 (20.4)	1.62 (44.2)	2.00 (3.1)	2.08 (3.5)	2.18 (4.0)	3.32 (10.7)
T_3	3.64 (13.1)	3.98 (15.6)	4.88 (24.1)	1.69 (52.8)	4.39 (18.8)	4.74 (22.5)	5.24 (27.9)	1.81 (69.3)	2.64 (6.2)	2.79 (7.2)	3.03 (8.6)	4.67 (22.0)
LSD (p=0.05)	0.05	0.06	0.08	0.02	0.07	0.09	0.09	0.02	0.04	0.12	0.04	0.09
Nutrient management practices (N)												
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Depths (C)												
D_1	3.51 (12.6)	3.86 (15.2)	4.92 (25.4)	1.66 (53.1)	3.98 (16.3)	4.65 (22.5)	5.48 (31.0)	1.78 (69.8)	2.43 (5.4)	2.75 (7.2)	2.88 (8.0)	4.42 (20.6)
D_2	2.52 (5.6)	2.92 (7.7)	3.63 (12.5)	1.42 (25.8)	3.12 (9.0)	3.48 (11.5)	4.06 (15.7)	1.56 (36.2)	1.91 (2.7)	2.03 (3.2)	2.18 (3.9)	3.24 (9.9)
D_3	1.98 (3.5)	2.31 (5.0)	2.85 (8.2)	1.13 (16.6)	2.74 (7.5)	2.78 (7.7)	3.16 (10.0)	1.32 (25.2)	1.67 (2.1)	1.59 (1.8)	1.72 (2.3)	2.41 (6.1)
LSD (p=0.05)	0.05	0.06	0.08	0.02	0.07	0.09	0.09	0.02	0.04	0.12	0.04	0.09
Tillage (T) × Nutrient management practices (N)												
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Tillage (T) × Depths (C)												
T_1D_1	2.20 (3.8)	2.43 (4.9)	3.00 (8.0)	1.27 (16.7)	2.53 (5.4)	2.86 (7.2)	3.61 (12.0)	1.43 (24.6)	1.57 (1.5)	1.84 (2.4)	1.87 (2.5)	2.71 (6.3)
T_1D_2	2.04 (3.2)	2.37 (4.6)	2.85 (7.1)	1.23 (14.9)	2.55 (5.5)	2.79 (6.8)	3.42 (10.7)	1.40 (23.0)	1.58 (1.5)	1.74 (2.0)	1.83 (2.3)	2.62 (6.0)
T_1D_3	1.11 (0.2)	1.30 (0.7)	1.55 (1.4)	0.64 (2.3)	1.55 (1.4)	1.53 (1.4)	1.87 (2.5)	0.86 (5.3)	1.26 (0.6)	1.30 (0.7)	1.64 (1.7)	2.00 (3.0)
T_2D_1	3.41 (10.6)	3.93 (14.5)	5.27 (26.9)	1.73 (52.0)	3.93 (14.4)	4.88 (22.8)	5.85 (33.3)	1.86 (70.5)	2.43 (4.9)	2.70 (6.3)	2.79 (6.8)	4.36 (18.0)
T_2D_2	2.45 (5.1)	2.97 (7.8)	3.88 (14.1)	1.46 (27.0)	3.08 (8.6)	3.57 (12.1)	4.30 (17.5)	1.60 (38.3)	1.91 (2.7)	1.99 (2.9)	2.11 (3.5)	3.17 (9.1)
T_2D_3	1.90 (2.6)	2.33 (4.5)	3.02 (8.2)	1.23 (15.3)	2.67 (6.2)	2.88 (7.3)	3.35 (10.4)	1.41 (23.8)	1.66 (1.7)	1.55 (1.4)	1.65 (1.7)	2.42 (4.9)
T_3D_1	4.92 (23.2)	5.21 (26.2)	6.50 (41.2)	1.97 (90.6)	5.47 (28.9)	6.21 (37.6)	6.98 (47.7)	2.07 (114.2)	3.29 (9.8)	3.71 (12.8)	3.97 (14.7)	6.20 (37.4)
T_3D_2	3.08 (8.5)	3.42 (10.7)	4.16 (16.3)	1.57 (35.4)	3.72 (12.8)	4.08 (15.6)	4.46 (18.9)	1.69 (47.3)	2.24 (4.0)	2.38 (4.6)	2.61 (5.8)	3.93 (14.4)
T_3D_3	2.93 (7.6)	3.29 (9.8)	3.98 (14.8)	1.53 (32.2)	3.98 (14.8)	3.92 (14.4)	4.27 (17.2)	1.69 (46.4)	2.39 (4.7)	2.27 (4.2)	2.51 (5.3)	3.90 (14.2)
LSD (p=0.05)	0.09	0.11	0.14	0.03	0.12	0.16	0.15	0.03	0.07	0.22	0.07	0.16

T_1: Conventional tillage - Sowing, T_2: Minimum tillage - Sowing, T_3: Zero tillage-Transplanting, N_1: 100% recommended NPK (50:40:25 kg NPK/ha), N_2: 100% recommended NPK + 7.5 t FYM/ha, N_3:Horsegram residue mulch + 100% recommended NPK, N_4: Horsegram residue mulch + 50% recommended NPK + 25 % N through FYM + *Azotobacter* seed treatment, N_5:Horsegram residue mulch + Fertilizers based on soil test results, D_1 - 0-10 cm, D_2 - 10-20 cm, D_3 - 20-30 cm. BLW-Broad leaved weeds, * - sqrt(x+1) transformation, # - log(x+2) transformation, Figures in parentheses indicate original values, LSD-Least Significant difference, NS-Non significant bank. Zero tillage resulted in the deposition of more seeds and propagules of predominant annual and perennial weeds near the soil surface (Subbulakshmi *et al*. 2009). Among different soil depths, 0-10 cm has a higher number of weed seeds as a result of soil inversion which brings the soil from the lower layer to the top layer, no soil disturbance under zero tillage and deposition of more number of weed seeds in the top layer and the lowest weed seeds at 20-30 cm soil layer was due to slower movement of these weed seeds to the lower layer. Among tillage and depth interactions, significantly higher weed seeds were observed on zero tillage and 0-10 cm interaction, due to no soil disturbance in zero tillage that too on top 0-10 cm soil surface layer have together responsible for higher weed seed bank at the top undisturbed layer. Whereas, lowest weed seed number in conventional tillage in 20-30 cm soil depth samples was because of intensive frequent tillage which has shifted lower soil depth weed seeds to the top layer and left the lower layer with fewer weed seeds. These outcomes are supported by Barberi *et al*. (2001) who quoted that vertical distribution of seeds will dictate which seeds produce potentially crop-competitive weeds.

The conventional tillage ((2 ploughings + 1 harrowing + 2 inter cultivation at 25 and 50 days after sowing (DAS)) was found better for effective management of weeds in finger millet crop on *Alfisols* due to reduced weed growth due to reduced soil weed seed bank with the improved grain and straw yield over the minimum and zero tillage practices. Whereas, the nutrient management practices have not significantly varied in the control of weeds. The application of 100% recommended NPK + 7.5 t FYM/ha has resulted in significantly higher grain and straw yields over other nutrient management practices.

ACKNOWLEDGEMENT

Authors sincerely acknowledge the AICRP on Dryland Agriculture, University of Agricultural Sciences, GKVK, Bengaluru for providing all the facilities for this field and laboratory studies and INSPIRE Fellowship given by Department of Science and Technology, Ministry of Science and Technology, Govt. of India for pursuing Ph.D. related research work of the senior author.

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