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Influence of nutrient management and crop rotation on soil weed seedbank in Tharaka Nithi County

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Abstract: Soil weed seedbank in crop fields are largely influenced by crop rotation, farming practices and nutrient application. For a better understanding of response of various weed species to these management practices, research was conducted to assess their effect on the soil weeds seedbank population dynamics in 2017-2019. In this study, two nutrient level i.e., 225 kg N ha^{-1} and 125 kg P ha^{-1} represented high nutrient input levels applied in commercial systems (Conv-High and Org-High) and 45 kg N ha^{-1} and 26 kg P ha^{-1} was used to mimic low nutrient practices common in smallholders farming systems (Conv-Low and Org-Low) in the region of Tharaka- Nithi County. Trials were laid out in a randomized complete block design with four treatments replicated four times. A crop rotation with maize, beans, potatoes and cabbage was used with maize/cabbage 1st year, maize/beans 2nd year and maize/potatoes 3rd year were established within the four farming systems. Soil was sampled at a depth of 0-20 cm at the end of every cropping season. The sample were treated with gibberellic acid to break weed seed dormancy and seed emergency method was used to determine weed seeds in the soil sample. Results were analyzed using Simpson's diversity index and GenStat 14th edition. From the result, 14 weed species were identified. *Amaranthus hybridus*, *Bidens pilosa*, *Tagete minuta* and *Galinsoga parviflora* increased in their density with increase in fertilizer application while *Schkurihria pinnata* and *Portulaca oleracea* increased with decrease in fertilizer application. Crop rotation resulted contributed to weed density decrease. Conventional high encouraged high weed density compared to Org-high, Conv-Low and Org-low while as Org-Low encourage high weed species diversity λ= 0.1208 compared to λ= 0.115, λ= 0.1080 and λ= 0.0901 in Org-high, Conv-High and Conv- Low, respectively. In weed management, fertility inputs and cropping system are the major factor influencing weed composition in farming systems.

1.0 Introduction

Weeds are threats to crop productivity that led to yield loss in both quality and quantity (MacLaren *et al*., 2020). Globally, yield loss resulting from weed has been estimated to be 34% which is higher than that caused by pests (18%) and pathogens (16%) (Gharde *et al*., 2018). This has been attributed to weeds being more adaptive and persistent than many crop varieties (Kaur *et al*., 2018). In case of poor weeds management practices, crop yield loss as a result of weed in Central Kenya range between 15% to 90% (Maina *et al*., 2003).

Cropping history and farming practices over time have a great influence on the weed communities (Gaba *et al*., 2014; Laita *et al.*, 2024). Composition of weed species and density in agricultural land has a direct correlation with the amount of fertilizer applied and the use of herbicide on these fields (Perotti *et al*., 2020, Gerhards *et al*., 2013). Therefore, combination of appropriate cropping strategies, with multiple weed stress approaches can be combined in weed management (Kumar *et al.*, 2019). Crop diversification changes weed spectrum and creates unfavorable conditions on the soil environment that hinders germination of some weed seed species (Gharde *et al.*, 2018). Weed seedbank in the soil is the major source of weed population in the field (Hossain and Begum, 2015).

Composition of weed species in the soil weed seedbank can be disrupted by farming activities and cropping systems such as crop rotation (Gharde *et al*., 2018). Despite so, understanding interactions between various types of crops used during rotation and their ability to prevent weed establishment or seed production is of great importance for effective weeds control (Schwartz-Lazaro *et al.*, 2021; Abouatallah *et al.*, 2011). Thus, for better weed control through crop rotation it's important to familiarize with factors such as crop type, inter-row spacing, type of fertilizer used as well as cropping season that influences weed density, dominance, and diversity (de Mol *et al.*, 2015). For successful weed suppression, a well-designed crop rotation and mostly the sequence in which they have to follow is of great importance (Gallandt, 2014). Having crops with different life cycles during the rotational practices can help in disrupting weed associated with certain agricultural conditions (MacLaren *et al.*, 2020). Use of diversified crop species helps in controlling certain weeds from dominating crop field particularly weeds that are associated with certain crops species (Sharma *et al.*, 2021). Moreover, evaluation of crop rotation should be done regularly to determine if problematic weeds are surviving crop rotation schemes and come up with new adjustments for effective weed management (Sharma et al., 2021; Otto et al., 2023).

In this case a better understanding of the response of various weed species to changing management practices is required (Ramesh et al., 2017) to help in developing improved weed management systems. Having information on the soil weed seedbank size and its composition provides insight on the processes of weed community transition that can be used for prediction of occurrence of various weed species and plan in advance an effect weed control measures (Hosseini *et al.*, 2014). Weeds species differ in dominance, density, and intensity in conventional and organic farming systems (Bajwa, 2014) with weed control methods applied in different parts of Kenya differing from one region to the other (Edgar *et al*., 2017). Therefore, there was need to understand how organic farming systems with rotation, cover cropping, and bio-pesticides affect weed density, dominance, and varieties relative to conventional systems with rotational cropping, synthetic pesticides, herbicides and fertilizers in Tharaka Nithi Counties. This work aimed on the following objectives: (i) to determine influence nutrient management practices on weed in organic and conventional farming systems and (ii) determine the effects of crop rotational on soil weed seedbank in organic and conventional farming system in Tharaka-Nithi county.

2.0 Methodology

2.1 Experimental design and treatments

The study was conducted between 2017-2019 within a field experiment initiated in 2007 in Tharaka Nithi County at Chuka at latitude 00° 07', 00° 26' and longitudes 37° 19', 37° 46' E. The area is characterized by biannual rain rainfall ranging between 1500-2400 (Recha *et al.*, 2012). Soil types are Humic Nitisol (Wagate *et al.*, 2010).

The field experiments were initiated in 2001 as a randomized complete block design with four treatment and four replicates comparing organic and conventional farming system (Figure 1) under two nutrients levels i.e., high, and low. Trial plots were measuring 8 m x 8 m with an inner net plot of 6 m x 6 m in which the soil samples were taken. Beans (*Phaseolus vulgaris*), cabbages (*Brassica oleracea*) and potatoes (*Solanum tuberosum*) were planted with maize (*Zea may*) being the main crop (Table 1). For the high inputs, fertility inputs were organic and synthetic fertilizers at 225 kg N ha^{-1} and 125 kg P ha^{-1} represented high nutrient input levels applied in commercial systems (Conv-High and Org-High) while 45 kg N ha^{-1} and 26 kg P ha^{-1} was used for low input farming systems (Conv-Low and Org-Low) (Table 2). Weed control was done by the use of a hoe on the side of organic farming while us herbicide application was done on the side of conventional farming.

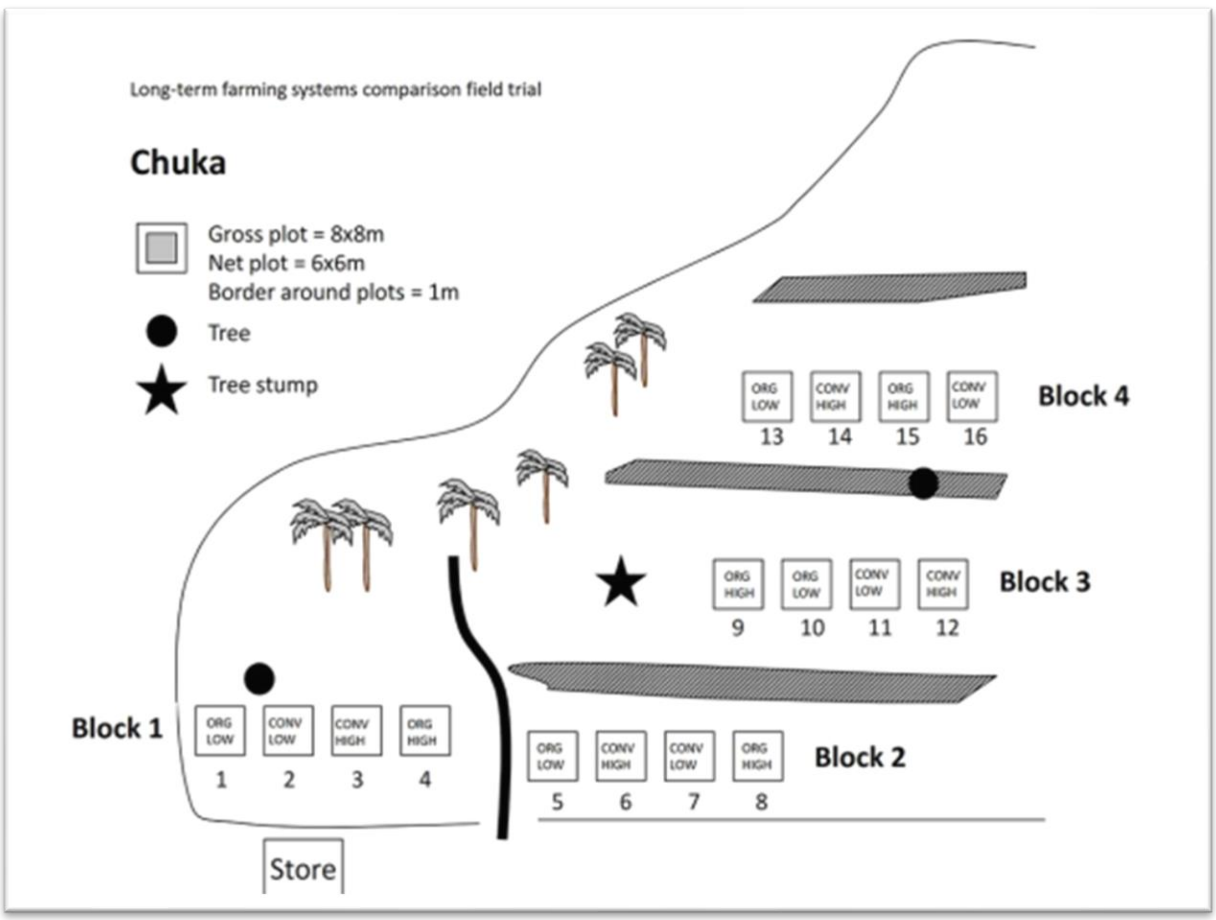

Figure 1: Randomized experimental trials layout in Chuka

Table 1: Crop sequence in three-year crop rotation in Chuka, where maize was the main crop preceded by vegetable, legume and tuber in conventional and organic low and high farming system.

Farming practice	2017		2018		2019	
	LS	SS	LS	SS	LS	SS
Con-High	Maize	Cabbage	Maize	Beans	Maize	Potatoes
Org-High	Maize	Cabbage	Maize	Beans	Maize	Potatoes
Conv-Low	Maize	Cabbage	Maize	Beans	Maize	Potatoes
Org-Low	Maize	Cabbage	Maize	Beans	Maize	Potatoes

Maize: *Zea mays L.*, Beans: *Phaseolus vulgaris L.*, Potatoes: *Solanum tuberosum*., Cabbage: *Brassica oleracea*., LS: Long rains season., SS: Short rain season.

Table 2: Fertility inputs in the long-term trials in Chuka

Treatments	**Farm inputs application per season**
Organic high	Organic fertilizer and rock-phosphate at 225kg N and 125 kg P/ ha/ year, and bio-pesticides
Organic low	Organic fertilizer at 45kg N and 26 kg P/ha/year no plant protection.
Conventional high	Inorganic fertilizers at 225kg N and 125 kg P/ ha/year, pesticides.
Conventional low	Inorganic fertilizers at 45kg N and 26 kg P/ha/year, pesticides at limited rates

Bio-pesticides used; Thuricide (*Bacillus thuringiensis* v. Kurstaki neem (*Azadirachta indica*) oil extract), Dipel (*Bacillus thuringiensis* v. Kurstaki + Achook), (*Azadirachta indica*), Fungi icipe isolate 30 (*Metarhizium anisopliae*) + Delfin (*Bacillus thuringiensis*).

2.2 Soil Sampling and weed assessment

Soil sampling was done at the end of every cropping season starting from August 2017. Soil weeds seedbank was determined in a greenhouse using seedling emergency method. Soil samples were passed through a 3 mm sieve to remove stones and pebbles that could hinder germination then treated with gibberellic acid to break weed seeds dormancy. A subsample of 500gms was placed in a germination trays, measuring 375 mm × 300 mm × 30 mm each which are best to ensure all weed germination (Lee *et al*., 2017). The trays used were perforated to allow excess water to drain. The controlled environment inside the greenhouse prevented weeds seed rain that could have been brought by wind to contaminate the set experiment. Temperatures inside the greenhouse were not controlled and each tray was watered using a spray bottle with 300 ml of water on each day to sustain a moderate soil moisture favorable for weed seeds to germination, all the trays were exposed to equal amount light that was evenly distributed inside the greenhouse.

Counting and identification of weed seedling to species started a week after germination has taken place for some weed species that are easily identifiable at the early stages. Others were allowed to grow to a point where they could be easily identified. Once the weed seedling was identified, it was recorded and then clipped off from the germination trays.

2.3 Data analysis

The following equation was used to determine weed density

$$\text{Weed density}(M^{-2}) = \frac{\text{No. seedling germinated X [Bulkdensity}(kgm^{-3})] \text{ X Sampling depth}}{\text{Dry weight of the soil sample (Kg)}}$$

Weed data were analyzed using GenStat software 14th edition (Payne *et al.*, 2011). Mean of weed species was compare using analysis of variance (ANOVA) and separation of means using Least Significant Difference (LSD) at $P \leq 0.05$. The weed species diversity in each rotational treatment was analyzed using the Shannon diversity index (H'); $H' = -\Sigma pi * ln(pi)$ (Sawicka *et al.*, 2020).

3.0 Result and Discussion

A total of fourteen weed species (Table 3) were recorded from the soil samples taken from the field within the three years in the six cropping seasons.

Table 3: Weed species identified in Chuka trials plots in the four farming systems.

Scientific name	Common names	Family	Life cycle
Amaranthus hybridus L.	Smooth pigweed	Amaranthaceae	Annual
Bidens pilosa L.	Black-jack	Asteraceae	Annual
Chenopodium album L.	lamb's quarters	Amaranthaceae	Annual
Commelina benghalensis L.	wandering jew	Commelinaceae	Perennial
Eleusine indica (L.) *Gaertner*	Goosegrass	Poaceae	Annual
Fallopia convolvulus (L.) *A.Love*	Black Bindweed	Polygonaceae	Annual
Galinsoga parviflora Cav.	Gallant soldier	Asteracea	Annual
Oxalis corniculata (L.)	Creeping woodsorrel	Oxalidaceae	Annual/Perennial
Portulaca oleracea L.	Purslane	Portulacaceae	Annual
Schkuhria pinnata (Lam.) *Thell.*	Dwarf Marigold	Schkuhria	Annual
Setaria verticillata L.	Bristly foxtail	Poaceae	Annual
Sonchus oleraceus L.	Sow thistle	Asteraceae	Annual
Stellaria media (L.) *Vill*	Chickweed	Caryophyllaceae	Perennial
Tagetes minuta L.	Mexican marigold	Asteraceae	Annual

3.1 Influence of crop rotation on weed density in organic and conventional farming systems

Weed density within the four farming systems was significantly *(P<0.001)* influenced by the type of crop in season. Maize-cabbage rotation in the year 2017 resulted to a significant *(P<0.001)* decrease in weed density by 54.6% and 30.0% in conventional high and conventional low, respectively (Table 4). In 2018, weed density decreased significantly *(P<0.001)* in maize-beans rotation by 72.2% and 4.7% in conventional high and conventional low. However, weed density increased by 3.3% and 4.3%, under organic high and organic low, respectively (Table 4). Weed density was significantly *(P<0.001)* affected by maize-potatoes rotation in 2019. This resulted in weed density increase at conventional high, conventional low and organic high by 36%, 54.5% and 33.5%, respectively. However, the rotation also caused a reduction in the weed density in organic low by 5.2% (Table 4).

Weed density was highly reduced under conventional high, conventional low, and organic low farming system compared to organic high farming system as a result of crop rotation within the three years. Variation of densities in weed species with change of crop type can be link to the association that weed develop towards certain type of crop and farming system *(Bajwa et al.*, 2015; Korav *et al*., 2018). Crop morphology and spacing are also major factors that influence weed density (Jha *et al*., 2017; van der Meulen and Chauhan, 2017). The effectiveness of crop alternation to lower weeds is highly inclined to the type of crops in season (Nichols *et al*., 2015; Melander *et al*., 2017).

Table 4: Weed density as influenced by crop rotation within the four farming systems during 2017-2019 cropping seasons in Chuka located in the Central Highland of Kenya

		Chuka			
		Weed density (No. of weeds m^{-2})			
Crop	**Season**	**Conventional high**	**Conventional low**	**Organic high**	**Organic low**
Maize	2017 LRS	185.7^{f}	64.7^{e}	88.0^{e}	52.3^{d}
Cabbage	2017 SRS	84.7^{d}	45.3^{d}	120.3^{f}	54.0^{e}
Maize	2018 LRS	94.7^{e}	34.3^{c}	60.7^{b}	49.0^{c}
Beans	2018 SRS	26.3^{b}	32.7^{b}	62.7^{c}	53.3^{d}
Maize	2019 LRS	25.3^{a}	22.0^{a}	53.7^{a}	33.0^{a}
Potatoes	2019 SRS	34.3^{b}	34.0^{c}	71.7^{d}	31.3^{a}
LSD		**0.73**	**0.30**	**0.43**	**0.72**
P- Value		**0.001**	**0.001**	**0.001**	**0.001**

Mean of value with the same letters in column are not significantly different at P≤0.05. *LRS- Long Rain Season, SRS-Short Rain Season*

Maize-beans crop rotation resulted in a decrease in weed density. The rotation practices have been used to manage weeds by many smallholders' farmers (Nurk *et al*., 2017; Andert, 2021). Research done by (Mhlanga et al. (2015) indicated that maize followed by beans crop rotation reduced weed density by 61.5%. These results were also affirmed by Rugare *et al*. (2019) on the efficiency of maize beans rotation which indicated a significant reduction of weed density by 59%. Maize-potatoes crop rotation resulted in in weed increase, this can be accredited to its the poor competition ability (Osmar Caldiz *et al*. (2016), where weeds are able to establish faster than the crop (Abdallah *et al*. (2021).

3.2 Influence of nutrient management on weed species density

The weed density of *Amaranthus hybridus*, *Bidens pilosa* and *Galinsoga parviflora* were significantly *(P<0.05)* higher by 28.5%, 63.4% and 4.8%, respectively at the start of the experimental season in 2017 under 225 N & 125 P compared to 45 N & 26 P applications. Their density decreased significantly *(P<0.05)* over the 2018 and 2019 cropping seasons except for *Bidens pilosa* which showed no significant difference by the end of the cropping seasons (Table 5).

Table 5: Weed species density (Plants M^{-2}) as influenced by different rates of N and P fertilizer application in Chuka located in the Central Highland of Kenya

Seasons	N & P application rates	A.H	B.P	C.A	C.B	F.C	G.P	O.C	P.O	S.P	S.V	S.O	T.M	S.M
LR 2017	225 N & 125 P	17.5e	20.5^{bcd}	0.0^{a}	0.0^{a}	0.0^{a}	21.0^{e}	17.0^{a}	6.0^{abc}	15.5^{bc}	24.0^{d}	11.5^{a}	0.0^{a}	4.5^{a}
	45 N & 26 P	12.5^{cde}	7.5^{ab}	0.0^{a}	0.0^{a}	3.0^{a}	20.0^{de}	13.5^{a}	15.0^{c}	22.5^{c}	10.0^{abc}	0.0^{a}	0.0^{a}	0.0^{a}
SR 2017	225 N & 125 P	0.0^{a}	16.5^{abcd}	1.5^{a}	0.0^{a}	3.5^{ab}	16.5^{bcde}	6.0^{a}	1.5^{ab}	13.5^{abc}	16.5^{cd}	1.5^{a}	1.0^{a}	0.0^{a}
	45 N & 26 P	1.0^{ab}	13.0^{abc}	0.0^{a}	4.0^{ab}	0.0^{a}	12.0^{bcd}	0.0^{a}	3.0^{ab}	16.0^{bc}	10.0^{abc}	2.5^{a}	0.0^{a}	2.5^{a}
LR 2018	225 N & 125 P	3.0^{abc}	16.5^{abcd}	0.0^{a}	0.0^{a}	1.5^{a}	19.5^{de}	5.5^{a}	1.5^{ab}	8.5^{ab}	12.5^{abcd}	2.5^{a}	4.5^{a}	2.5^{a}
	45 N & 26 P	11.0^{bcde}	10.5^{abc}	0.0^{a}	0.0^{a}	7.0^{ab}	11.0^{abc}	13.0^{a}	3.0^{ab}	11.5^{abc}	7.0^{abc}	0.0^{a}	0.0^{a}	7.5^{a}
SR 2018	225 N & 125 P	4.5^{abc}	16.5^{abcd}	10.5^{a}	0.0^{a}	10.5^{b}	14.5^{bcde}	10.5^{a}	11.0^{bc}	6.0^{ab}	11.5^{abc}	7.0^{a}	2.0^{a}	0.0^{a}
	45 N & 26 P	0.0^{a}	6.5^{a}	0.0^{a}	0.0^{a}	0.0^{a}	13.0^{bcde}	4.0^{a}	3.5^{ab}	7.0^{ab}	4.0^{a}	1.0^{a}	0.0^{a}	9.5^{a}
LR 2019	225 N & 125 P	1.0^{ab}	29.5^{d}	4.0^{a}	0.0^{a}	0.0^{a}	17.5^{cde}	2.0^{a}	0.0^{a}	13.0^{abc}	4.5^{ab}	1.0^{a}	1.0^{a}	1.5^{a}
	45 N & 26 P	4.0^{abc}	7.5^{ab}	0.0^{a}	1.5^{a}	0.0^{a}	3.5^{a}	6.5^{a}	0.0^{a}	8.0^{ab}	5.0^{abc}	0.0^{a}	0.0^{a}	0.0^{a}
SR 2019	225 N & 125 P	6.0^{abcd}	23.0^{cd}	11.5^{a}	16.0^{b}	0.0^{a}	14.0^{bcde}	3.0^{a}	2.0^{ab}	4.0^{a}	16.0^{bcd}	6.5^{a}	0.0^{a}	5.5^{a}
	45 N & 26 P	16.0^{de}	4.50^{a}	0.0^{a}	0.0^{a}	0.0^{a}	9.0^{ab}	6.0^{a}	1.0^{ab}	8.5^{ab}	6.0^{abc}	2.0^{a}	0.0^{a}	0.0^{a}
	LSD	**10.9**	**13.6**	**14.6**	**14.3**	**7.4**	**8.5**	**17.2**	**10.5**	**11.2**	**11.8**	**13.7**	**4.6**	**10.9**
	P-value	**0.029**	**0.039**	**0.62**	**0.499**	**0.118**	**0.023**	**0.597**	**0.116**	**0.117**	**0.071**	**0.77**	**0.061**	**0.594**

225 kg N ha^{-1} and 125 kg P ha^{-1} denotes; Conv. High and Org. High and 45 kg N $ha^{-1}$and 26 kg P ha^{-1} represent; Conv. Low and Org. low. A.H-*Amaranthus hybridus*; B.P-*Bidens pilosa*; C.A-*Chenopodium album*; C.B-*Commelina benghalensis*; F.C-*Fallopia convolvulus*; G.P-*Galinsoga parviflora*; O.C-*Oxalis corniculata*; P.O-*Portulaca oleracea*; S.P-*Schkuhria pinnata*; S.V-*Setaria verticillata*; S.O-*Sonchus oleraceus*; T.M-*Tagetes minuta*; S.M-*Stellaria media*. *Column with means with the same letter shows no significant difference at P<0.05*

The densities of *Chenopodium album*, *Commelina benghalensis*, *Fallopia convolvulus*, *Oxalis corniculata*, *Setaria verticillata*, *Sonchus oleraceus* and *Stellaria media* decreased (*not statistically significant*) with the decrease in fertilizer application rates within the six cropping seasons (Table 5). Contrary, in 2017 long rain and short rain season, the density of *Schkurihria pinnata* and *Portulaca oleracea* was higher by 38% and 42.9% during the long rains and 29.5% and 33.3% during the short rains, respectively with decrease in the application rates of N and P. The density of *Schkurihria pinnata* remained high under the low application rates in 2017 SR, 2018 LR, 2018 SR and 2019 SR. Low application rates of N and P hindered the presences of *Chenopodium album* in 2017 SR, 2018 SR, 2019 SR and 2019 LR and in *Tagete minuta* in 2017 SR, 2018 LR and 2018 SR (Table 5).

Application of fertilizer changes soil fertility, which impacts crop growth and weed density and species composition on the farm (O'Donovan *et al*., 1997; Abouatallah *et al*., 2012). The type of fertilizer differs between organic and conventional farming systems (Araújo *et al*., 2008; Montgomery & Biklé 2021) which also influences weed species distribution (Kordbacheh *et al*., 2023). Inorganic fertilizer releases nutrient faster than organic fertilizer which affects nutrient uptake by crop and weeds as well as weed composition (Mahé *et al*., 2021; Kakabouki et al., 2020). The rate and the type of fertilizer influences different weed species differently as different species have different demand for various nutrients (Baker *et al*., 2018).

Some weed species thrive well under high soil fertility e.g., *Amaranthus hybridus*, *Bidens pilosa*, *Galinsoga parviflora* and *Commelina benghalensis* which are used by farmers in Chuka as major indicators of soil fertility (Mairura *et al*., 2008). This shows that high fertilizer application rates enable the weed species to grow faster and produce more seeds (Desbiez *et al*., 2004). Other weed species such as *Portulaca oleracea*, *Tagetes minuta* and *Schkuhria pinnata* are associated with low soil fertility (Mairura *et al*., 2008; Handa *et al*., 2012).

3.3 Influence of farming system and on weed diversity

The organic low farming system indicated a diversity index of 0.1208 followed by Org-High, 0.1115 and Conv-High with 0.1080. Conv-Low indicated low diversification of weed species with diversity index of 0.108 (Figure 2). Results from Simpson's diversity index showed that Organic farming practices encourages species diversification.

This coincides with findings by (Armengot *et al*., 2013) which stated high Shannon diversity index in organic weed communities and low Shannon index in conventional farming system. Lower Shannon diversity index under conventional farming systems can be attributed to continuous herbicide application which leads to complete elimination of weed species that are highly susceptible to herbicide application (Berbeć *et al*., 2020). Other researchers observed when studying the influence of farming system on the development and yield of yellow lupin, that seed yield was 13.1% and 22.0% greater in the medium-input (medium fertilization level and chemical protection), and high-input (high fertilization level and chemical protection) systems, respectively, than in low-external inputs (without fertilization and chemical protection). Their research also highlighted differences in cultivar yield; the indeterminate cultivar Mister produced more seeds than the determinate cultivar Perkoz (1.95 t ha^{-1} vs. 1.81 t ha^{-1}) (Szymańska *et al*., 2017).

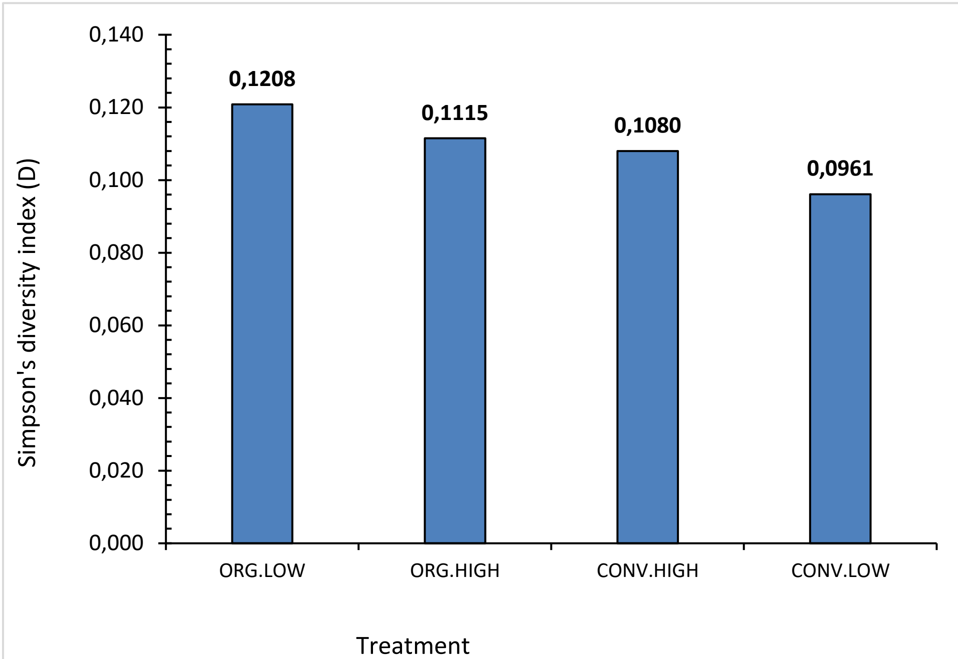

Figure 2: Simpson's species diversity index in the four-farming system.

Summary

No	Objective	Effect / influence
1	Fertilizer effect on weed	➢ *Amaranthus hybridus*, *Bidens pilosa*, *Galinsoga parviflora* and *Commelina benghalensis* increase with increase on soil fertility. ➢ *Portulaca oleracea*, *Tagetes minuta* and *Schkuhria pinnata* increase with decrease in soil fertility
2	Effect of crop rotation on weed	➢ Crop rotation resulted to decrease in weed density with maize-beans rotation being the most effective
3	Influence of farming system on weed diversity	➢ Organic farming practices encourages species diversification or conventional farming led to decrease in species

Conclusion

Crop rotation resulted to weed decrease within the four farming systems. This affirms other findings on use of crop rotation as a tool on weed management. Rotation of maize with cover crop ultimately reduced weed density in both organic and conservation farming systems. Application of 225 N kg/ha and 125 P kg/ha resulted to a significant *($P<0.001$)* high weed density in contrast with 45 N kg/ha and 26 P kg/ha. The type of fertility input and the amount of application influences weed diversity and density. This study proves that organic farming practices results to higher weed diversity compared to conventional farming system.

Competing Interests: Authors have no competing interests to declare.

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