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Weed Communities Responses to Different Fertilizer Managements in Summer Maize Field

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Abstract: The impacts of long-term diverse fertilizer managements on weed species and communities were studied in experimental plots of irrigated field established in 1990 at Wuquan village, Yangling, China. This study was demonstrated that the randomized complete block design with 5 replications in summer maize season. Effects of diverse fertilizer managements on crop and weed growth, thus on influences of farmland biological diversity. Treatment without N or P, affects not only weeds species but also weed diversity indices. N fertilization could influence the species richness and diversity, also dominant the weed population size and consequently it could change the level of community evenness. P fertilizer application would change the presence of weed species in the field reasonable balanced fertilization (NPK) treatment can control species types and maintaining the role of farmland ecosystem biodiversity.
Keywords: nutrient management, weed community, three diversity indices

INTRODUCTION

A weed is a plant considered undesirable in a particular situation, "a plant in the wrong place". Examples commonly are plants unwanted in human-controlled settings, such as farm, fields, gardens, lawns, and parks. Weeds are one of the greatest limiting factors to efficient crop production [1]. However, as one of the primary producers within farming systems, weeds are of central importance to the arable system's food web [2]. Weeds also have other ecosystem functions, including nutrient cycling and soil preservation. The biodiversity of weed communities in a cropland can therefore be an important element for the reliable and sustainable provision of agro ecosystem services. However, encouraging in-field biodiversity is unpopular among farmers because of the risk of decreased crop production as a result of weed competition [3]. Weed community was influenced both directly by the fertilizer and indirectly by increased competition with the crop. The diversity of weed communities will determine the nature of weed management strategies required and changes in diversity may be indicative of potential weed management problems [4].

Fertilizer is any material or substance applied to the plant for the provision of essential nutrients for their better growth and development[5].Fertilization alters soil fertility, thus affecting weed density nutrient uptake, and biomass yield, which in turn affects species composition and biodiversity [6-11]. Fertilizer placement is considered one of the important components of cultural weed management programs [12, 13] as fertilizer placement can markedly influence the competitive ability of crops and interference from weeds [5]. Cropping system and fertilization may influence weed composition indirectly by influencing nutrient and radiation competition between crops and weeds. Varying physiological responses of weed species to soil amendments are one of the explanations for weed community biodiversity [14].

Understanding the shifts in weed community composition under different fertilization treatments would help in designing effective weed management programs, and identifying species indicators of soil nutrient availability. [15, 16] Additionally, weed management systems that emphasize competitive crops and would help achieve the many advantages of fertilizer application to crop production. In recent years, many researchers showed that fertilization had profound influences on the weed community in crop field. The soil nutrition results in large differences in the species diversity of the weed community. The degree of influence of the different nutrition elements on the weed community varied [17]. The information from several studies suggests that manipulation of fertilizer placement is a promising weed management approach to reduce weed competition in crop [18, 19].

Nowadays, most weed research has been devoted to the study of weed characteristics, mainly crop–weed competition responses to fertilization or weed communities alone. These investigating provide a basis for the study of long-term diverse fertilizer management effects on weed community diversity in summer maize season. The aim of this study was to understanding the effects of long-term diverse fertilization system on weed species and communities under different cropping system in summer maize field.

MATERIALS AND METHODS

Study site & Experimental design

A long-term field experiment was conducted in 1990 at the experimental center for the Chinese National Soil Fertility and Fertilizer Efficiency Monitoring Base of Loess Soil (at 34° 17′ 51″ N and 108° 00′ 48″ E, with altitude of 524.7 m above sea level) in Wuquan village, Yangling district, Shaanxi province, Northwest China. The type of soil of the site was loess soil containing clay 32 %, silt 52 % and sand 16 %. In this study site, mean annual temperature was 12.9 °C and mean annual precipitation is 550 mm which is mainly achieved from July to September. Seven treatments with 5 replicates in randomized complete block design were established, under irrigated cropping system for this long-term experiment. The treatments were no fertilizer or manure inputs (control, hereafter CK); various combinations of inorganic N, P and K fertilizers, including N, NK, NP, PK, NPK, NPK plus wheat straw or maize stalk (SNPK) and the following numbers indicate rates of manure amendment) see Table-1 for details. The experiment was carried out as the summer season maize from July to October 2015.The plots were irrigated with ground water 2 to 4 times during the summer maize annually. At the time of experimental center establishment, the soil contained 7.44 g kg^{-1} organic C, 0.93 g kg^{-1} total N, 9.57 mg kg^{-1} Olsen-P, 191 mg kg^{-1} exchangeable K, 92.5 g kg^{-1} $CaCO_3$ with having pH of 8.62 across all plots [20, 21].

Weed sampling and Data Analyses

The investigation of the weeds were recorded in five 1m^2 quadrats distributed randomly in each treatment plot during the period from 7-8 leaf stage to two weeks before harvest of summer maize (July-September,2015).Weed species occurred on that field were identified and recorded for this study according to the handbook [1982]. Light transmittance within the canopy was measured with a digital light meter **(TES-1330) TES (Electrical Electronic Crop China)** above the crop and on the soil surface.

The raw density data for weed species were used to calculate the three diversity indices. The species diversity was determined using the Shannon's diversity index (*H′*) [Putman & Wratten, 1984]

$$H' = \sum_{i=1}^{s} \left(\frac{n_i}{N}\right) In \left(\frac{n_i}{N}\right) \quad (1)$$

Where, S = total number of species, N = total number of individuals of all the species, and n_i = number of individuals of the i^{th} species.

The community dominance was determined using the Simpson's index of evenness (E) [Parish et al., 1995]

$$E= H' /In\ N \quad (2)$$

The richness index was determined using the Margalef's richness index (D_{MG}) [Margalef, 1958]

$$D_{MG} = (S-1)\ (In\ N) \quad (3)$$

STATISTICAL ANALYSIS

The primary data were computed using Microsoft Excel 2010 spreadsheets. Results of the different treatments were tested by analysis of variance and mean values were compared using SPSS23.0. (SPSS: An IBM Company, Chicago, IL, USA) to calculate least significant difference (LSD) at 5% level. Weed community composition was analyzed by using the principal component analysis (PCA) [Benoit et al., 1992; Derksen et al., 1993, 1994, 1995].

RESULTS

Weed density and species composition in Summer Maize field in Summer Maize field

Fertilization have significantly influenced on the density of weed communities in summer maize field (Figure-1). Weed density was substantially lower with the balanced fertilization treatments (NP, NPK and SNPK) compared with treatments receiving no (CK) or unbalanced fertilization (N, NK, and PK) (Figure-1).

A total of 19 weed species from families were recorded in summer maize field. Out of 19 weed species, six weed species, such as: *Acalypha australis L. (Euphorbiaceae), Aventa fatua L.(Poaceae), Brassica rapa (Brassicaceae), Chenopodium glaucumL. (Amaranthaceae), Cirsium arvense (Compositaceae),* and *Cynodon dactylon (Poaceae)* had high weed densities and were widely distributed in all various treatments in summer maize field. *Setaria virids L.* was occurred as dominant species in the NK treatment also *Cyperus rotundus L.*species as dominant species occurred in PK treatment (Table 2). Nineteen kinds of weed species, 16 kinds of weed as annual weed species, and three kinds of weed were as perennial weed species. According to the result showed, weed species diversity changes with a combination of nutrient gradient varies, (N, CK, PK, NK, SNPK, NPK) treatments 8 to 10 species and CK, NK, and NP treatments, weed species was 10-14. The highest number of weed species was occurred in PK treatment.

Classification of weed species on the basis of morphotype and life cycle demonstrated that the monocotyledonous perennial weeds had the highest proportion (48%) and dicotyledonous perennial had 24% and dicotyledonous annual weed species had 15%, respectively and monocotyledonous annual had the lowest proportion (13%) among the life forms under irrigated cropping system (Figure -2).

Effects of diverse fertilizer management on weed diversity indices

Table (3) showed that the effects of diverse fertilizer management on weed management on weed community indices. Shannon's *H'* was used as a composite index of diversity since it incorporates both species evenness and species richness. According to this measure in maize field, diversity index was significantly decreased under SNPK and PK treatments (Table 3) but increased under other treatments. The lowest species evenness *E* index was occurred in PK and SNPK treatments and highest index was under other treatments. Highest species richness D_{MG} was occurred under treated soil in wheat field but not in maize field. The highest species richness was under PK treatment in maize field. In maize field, diversity index was significantly different under N treatment only but increased under other treatments. The species evenness index *E* was lower also only under N treatment and increased in other treatments.

Table 1: Details of fertilizer treatments and fertilizer rates for the cropping system (kg ha^{-1})

Treatments	Irrigated system		
	N	P	K
CK	0	0	0
N	165	0	0
NK	165	0	68.5
PK	0	57.6	68.5
NP	165	57.6	0
NPK	165	57.6	68.5
SNPK	165.0+40.4^{a}	57.6+3.8^{a}	68.5+138.9^{a}

[a] The amount of N/P/K contained in the added crop straw.

Table 2: Species composition and density of weeds in summer maize field under long-term diverse fertilizer managements

Species name*	Treatments						
	CK	**N**	**NK**	**PK**	**NP**	**NPK**	**SNPK**
Acalypha australis Linn.	1.5^{b}	0.5^{b}	1.2^{c}	2.1^{b}	3.7^{ab}	1.1^{ab}	5.6^{a}
Avena fatua Linn.	0.5^{b}	2.5^{b}	2.9^{c}	0.2^{b}	0.9^{b}	1.0^{ab}	0.0^{b}
Bidens biternata	0.8^{b}	0.0^{b}	0.0^{c}	0.1^{b}	0.0^{b}	0.0^{b}	0.0^{b}
Brassica rapa.	1.4^{b}	0.3^{b}	0.7^{c}	0.8^{b}	1.0^{b}	0.3^{b}	0.6^{b}
Calystegia hederacea	10.6^{b}	2.0^{b}	1.6^{c}	1.1^{b}	0.3^{b}	0.0^{b}	0.4^{b}
Chenopodium glaucum Linn.	0.3^{b}	0.6^{b}	5.3^{b}	0.4^{b}	0.2^{b}	0.4^{b}	1.9^{b}
Cirsium arvense	7.3^{b}	0.7^{b}	0.3^{c}	1.4^{b}	0.4^{b}	0.2^{b}	0.4^{b}
Coronilla varia Linn.	0.0^{b}	0.0^{b}	0.0^{c}	0.0^{b}	0.0^{b}	0.2^{b}	0.0^{b}
Cynodon dactylon	21.0^{a}	67.1^{a}	0.0^{c}	5.4^{b}	9.5^{a}	6.8^{a}	8.9^{a}
Cyperus rotundus Linn	0.0^{b}	0.0^{b}	0.0^{c}	23.1^{a}	0.0^{b}	0.0^{b}	0.0^{b}
Erigeron annuus	0.0^{b}	0.0^{b}	0.0^{c}	0.3^{b}	0.0^{b}	0.0^{b}	0.0^{b}
Erysimum cheiranthoides	0.1^{b}	0.0^{b}	0.0^{c}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
Eschenbachia japonica	0.1^{b}	0.0^{b}	0.1^{c}	0.3^{b}	0.0^{b}	0.1^{b}	0.0^{b}
Euphorbia helioscopia	0.0^{b}	0.1^{b}	0.0^{c}	0.1^{b}	0.4^{b}	0.1^{b}	0.1^{b}
Euphorbia humifusa.	0.1^{b}	0.1^{b}	0.0^{c}	0.0^{b}	1.0^{b}	0.1^{b}	0.0^{b}
Lathyrus latifolius	0.0^{b}	0.0^{b}	0.0^{c}	0.1^{b}	0.0^{b}	0.0^{b}	0.0^{b}
Setaria viridis (Linn.)	0.0^{b}	0.0^{b}	21.4^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
Veronica persica	0.1^{b}	0.0^{b}	0.2^{c}	0.4^{b}	0.0^{b}	0.0^{b}	0.1^{b}
Vicia cracca	0.0^{b}	0.0^{b}	0.0^{c}	0.1^{b}	0.0^{b}	0.0^{b}	0.0^{b}

[*] Classification according to the handbook of 陕西农田杂草图志, 1982, China. Different letters within same column indicate significant differences ($p<0.05$). Treatments are explained in Table-1.

Table 3: Diversity indices of weeds in summer maize field under long-term diverse fertilizer management

Treatments	Index		
	H'	*E*	D_{MG}
CK	0.52[a]	0.14[b]	1.55[b]
N	0.21[b]	0.05[c]	1.30[b]
NK	0.50[a]	0.15[b]	1.66[b]
PK	0.51[a]	0.16[b]	2.09[a]
NP	0.50[a]	0.19[ab]	1.65[b]
NPK	0.42[a]	0.19[ab]	1.65[b]
SNPK	0.48[a]	0.17[b]	1.42[b]

H' (Shannon Diversity Index), ***E*** (Evenness Index), D_{MG} (Richness Index). Different letters within same column indicate significant differences at 0.05 level ($p<0.05$). Treatments are explained in Table-1.

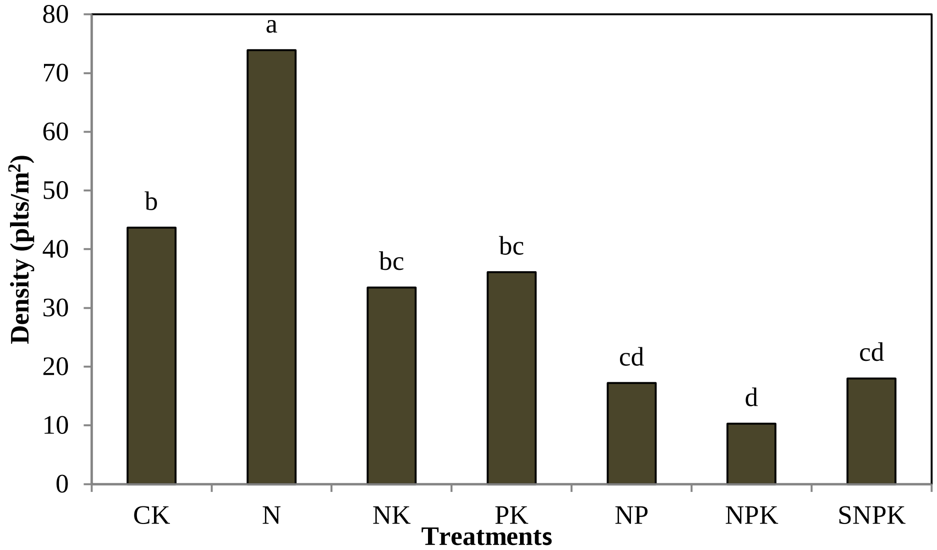

Fig 1: Density of weed communities (plants m^{-2}) in different fertilization treatments. Different lowercase letters on top of the bars represent significant difference between treatments at a 0.05 level (LSD test; *P*<0.05). CK; N; NK; PK; NP; NPK; SNPK; residual crop material returned with NPK.

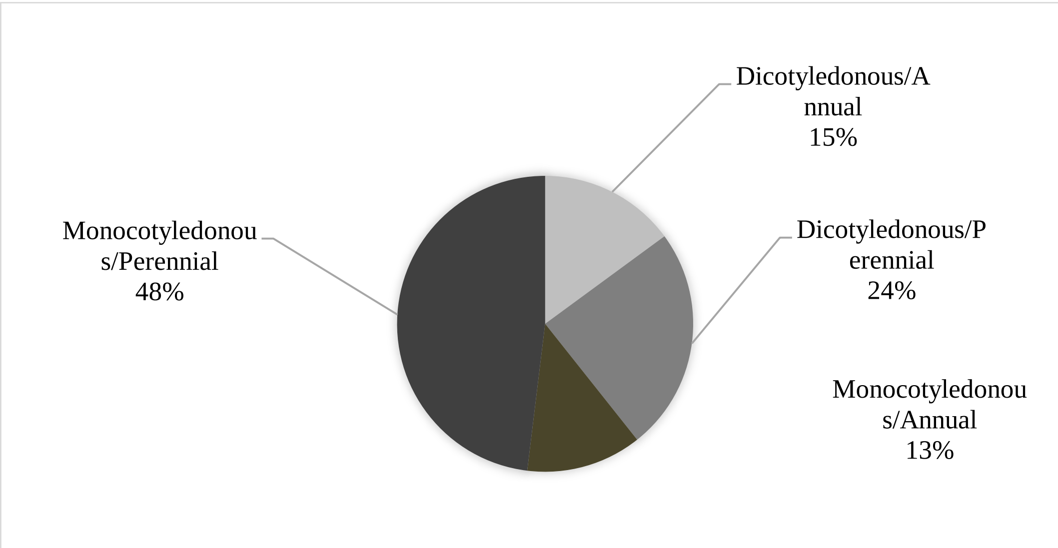

Fig 2: Comparison of the life forms of weed species present in summer maize field

DISCUSSION

Under diverse fertilizer managements changes the weed community diversity may be due to the changes in soil nutrients. In a study of long-term localized experiments that were started in 1990, they also found that the levels of fertility affected the individual levels of weed species and community [22]. As a result of this study, in summer maize season the N treatment showed that the highest weed density, followed by the CK, PK and NK treatments, while the balance fertilization treatment (NPK) resulted in lower values in summer crop fields. Some species, such as *Acalypha australis Linn Cynodon dactylon* and *Chenopodium glaucum Linn* were found as dominant species as widely distributed in all treatments taking great dominant in the communities [Tables 2]. Lichu Yin *et al.;* in 2005 suggested that some different relationship between weed species and fertilization treatments. Many weed species responded positively to increasing amount of soil N or P, but the magnitude of the response varied markedly among species [23, 24]. In this experiment total weed density in the N and N-deficiency in the PK treatments were high, while it was lower level of weed density in balanced fertilizer treatment (N, P, K) in crop season. Other studies [20, 25] long-term different fertilization treatment resulted change in soil nutrient conditions, causing external weeds to survive. The changes of environmental conditions, and various kinds of weeds change reaction and adaptation ability differences [26, 27], at the same time, may be due to the different species of weeds in poor tolerance and soil nutrient characteristics of different fertilizer, the change of the growth conditions are influenced by different degrees [28, 29]. Based on the results of this study, the total number of dicotyledonous (broad-leaves) weed species was higher than that of monocotyledonous (narrow leaves) weed species (Figure -2). According to the Derksen *et al.;* (2002) [30] who has found that composition of weed flora in cropping systems may be due to the seasonal changes, crop rotation, long-term environmental changes such as soil erosion and climate changes.

CONCLUSION

The present study highlighted that keep certain weed biological diversity for the protection of natural enemies, prevent soil erosion and promote nutrient cycling, maintenance of ecosystem function and maintain ecological balance plays an important role. Effects of diverse fertilizer management on crop and weed growth, thus on influence of farmland biological diversity. Under CK, N, NK, and PK treatments, total weed density was high in summer maize season. Treatment without N or P, affect not only weed species but also on weed diversity indices. N fertilization could influence the species richness and diversity, also dominant the weed population size and consequently it could change the level of community evenness. Phosphorus fertilizer application would change the presence of weed species in cropland. Reasonable balanced fertilization (NPK) treatment can control specific types, balance agricultural production and protection of farmland ecosystem in wild plant diversity contradiction, especially the rare species and rare species protection, to play its part in maintaining the role of ecological balance. As the nutrient inputs were increased in the fertilized plots, however, it is difficult to differentiate the role of nutrient losses played by weed cover in soil fertility maintenance and further studies are needed to confirm this result.

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