Retraction Notice

Title of retracted article: Long-Term Diverse Fertilizer Management on Weed Species and Communities in Winter Wheat Field

Author(s): Ni Ni Than, Shulan Zhang, Benhua Sun, Hua Yi, Xueyun Yang*

* Corresponding author. Email: 1918378198@qq.com

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The first author didn't get permission to publish this paper from her supervisor, Prof. Xueyun Yang.

This article has been retracted to straighten the academic record. In making this decision the Editorial Board follows COPE's Retraction Guidelines. Aim is to promote the circulation of scientific research by offering an ideal research publication platform with due consideration of internationally accepted standards on publication ethics. The Editorial Board would like to extend its sincere apologies for any inconvenience this retraction may have caused.

Editor guiding this retraction: Prof. Sukumar Saha (EiC, AJPS)

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Long-Term Diverse Fertilizer Management on Weed Species and Communities in Winter Wheat Field

Ni Ni Than[1], Shulan Zhang[1], Benhua Sun[1], Hua Yi[2], Xueyun Yang[1]*

[1]College of Natural Resources and Environment, Northwest A & F University, Yangling, China
[2]College of Life Sciences, Northwest A & F University, Yangling, China
Email: *1918378198@qq.com

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Abstract

We investigated the effects of different fertilization on weed community composition in long-term cropping experimental plots established 25 years previously in Wuquan, Yangling district, Shaanxi province, north-west China. Our study has focused on the different fertilization systems which would have a significant influence on weed communities in winter wheat field. The field experiments were carried out with seven different fertilization treatments, i.e. no fertilizer or manure input (control, hereafter CK) and various combinations of synthetic nitrogen (N), phosphate (P) and potassium (K) fertilizers, as N, NK, PK, NP and NPK, and dairy manure MNPK. The results revealed the presence of 19 weed species in total, representing 10 families and 19 genera. Higher weed densities and richness indices were observed with treatments receiving no (CK) or unbalanced fertilization (N, NK, PK), whereas lower weed densities and richness indices were found with balanced fertilizer application treatments (NP, NPK and NPK with organic manure). The results also demonstrated that the application of N and P fertilizer had a greater impact on the weed community than the application of K fertilizer.

Keywords

Weed Density, Nutrient Management, Diversity Index, Winter Wheat

1. Introduction

Weeds are plant species which grow in where they are not wanted, or in a wrong place, such as fields, gardens, lawns and parks. Weeds are varying from other plants species in being more destructive and they have eccentric characteristics that can make them more competitive. Most of studies are well documented that weeds cause decreasing in crop yield and quality by competing for available resources such as water, nutrient, space and light [1] [2] [3]. However, weeds can maintain the stability and sustainability of an agro-ecosystems [4], because they often contribute to relief in soil and water conservation and nutrient retention for improve soil productivity [5] [6], and can provide food for many species of beneficial insects, mainly crop pollinators [7]. It is for this reason that it investigated the impact of management practices on weed communities for use in weed management practices.

Weed communities are affected by many factors as agricultural management practices [8] [9], particularly crop rotation type [10] [11], different tillage systems [12], fertilization [13]. Fertilization affects not only the growth of crop but also on weed population [14] [15] [16]. Previous studies have been demonstrated that fertilization can significantly affect weed community composition, density and diversity [17] [18] [19]. For example, N application has increased crop yield but that can have altered effects on weed community structure [13] [20] but other studies have shown that the rate of N application has little effect on the competitive ability of crop and weed species [21] [22]. Moreover, some researchers have shown that P fertilizer increases the density of weed communities in crop fields than N and K fertilizers [23] [24] [25]. As suggested by Tang [3] has demonstrated that balanced fertilization was more efficient to prohibiting for growth of weeds. The application of chemical fertilizer with manure has increased the density of the weed community [26]. However, Miyazawa [27] and Menalled [28] indicated that manure application had influenced on weed infestation, but it may introduce new weed species. Based on these findings, it provides a basis for study of weed community response to fertilization, which is important for weed management programs in agricultural ecosystems.

Long-term field experiments are important to evaluate the changes of weed community composition and provide an understanding of the long-term effects. Many short-term experiments have been studies how crop rotation and fertilizers influences on weed communities. However, weed community responses to long-term fertilizer management have been rarely studied. The effects of different fertilizer application on weed community composition was studied in a 27 years long-term fertilizer experiment in winter wheat field. The present study was conducted to examine the response of weed community to long-term different fertilizer managements in winter wheat field. Understanding the changes in weed community composition under long-term different fertilizer management would help in regional weed management programs.

2. Materials and Methods

2.1. Study site & Experimental Design

Long-term field experiments were established in 1990 at the experimental station for the *Chinese National Soil Fertility and Fertilizer Efficiency Monitoring Base of Loess Soil* (located 34˚17'51''N and 108˚00'48''E, at an altitude of 524.7 m above sea level), in Wuquan, Yangling region, Shaanxi province, north-west

China. The soil at the site is a silt clay loam (32% clay, 52% silt and 16% sand; Eumorthic Anthrosol) derived from loess material. The study site had a mean annual temperature of 13˚C and mean annual precipitation of 550 mm, which fell mainly between July and September.

The field experiment included seven treatment plots with five replicates in a randomized complete block design, with a series of 196 m^2 (14 m × 14 m). The treatments were no fertilizer or manure input (control, hereafter CK) and various combinations of synthetic nitrogen (N), phosphate (P) and potassium (K) fertilizers, as N, NK, PK, NP and NPK, and dairy manure (MNPK, where M refers to dairy manure). Details of the amounts of each fertilizer used in the different treatments were given in Table 1. The N-containing inorganic fertilizer used in the experiment was urea; P was added as single super-phosphate, and K as potassium sulfate. Winter wheat was sown with a density of (180 $kg \cdot ha^{-1}$) seeds per hectare on October and harvested in June. Weeds were controlled by manually during the crop growing season. All plots were conventionally tilled with a rototiller.

2.2. Weed Sampling and Data Analyses

The weeds were recorded in five 1-m^2 quadrats distributed randomly in each treatment during the booting stages of winter wheat season. Weed species occurred in each quadrat were identified and recorded according to the ***Illustrated handbook of Weeds in Arable Land in Shaanxi Province*, 1982** [29]. Light transmittance within the canopy was measured with a digital light meter (**TES-1330) TES (Electrical Electronic Crop China**) above the crop plant and on the soil surface. Soil sample were taken in each plot to analyze the amount of total N, available P and K, and organic matter referred methods from Bao [30].

The diversity indices were calculated from the data of raw density of weed species data (Magurran AE, [31]). Species diversity was determined using the Shannon's diversity index (H'):

$$H' = \left(N \log N - \sum n \log n\right) N^{-1} \quad (1)$$

Table 1. Details of fertilizer treatments and fertilizer rates in winter wheat season for investigated cropping system ($kg \cdot ha^{-1} \cdot yr^{-1}$).

Treatments	N	P	K
CK	0	0	0
N	125	0	0
NK	125	0	68.5
PK	0	57.6	68.5
NP	125	57.6	0
NPK	125	57.6	68.5
MNPK	47.5 + 105.5a	57.6 + 115.9a	68.5 + 108.9a

[a]The amount of N/P/K contained in the added organic manure.

where, N is the total number of weed density in a plot and n is the number of individuals of the weed species in a plot.

The community dominance was determined using the Peliou's index of evenness (E)

$$E = H'/InN \tag{2}$$

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

$$D_{MG} = (S-1)(InN) \tag{3}$$

where, S is the number of the species in each plot.

2.3. Statistical Analysis

The primary data were computed by using Microsoft Excel 2010 spreadsheets. Results of the different treatments were analyzed ANOVA to evaluate differences between treatments and means were compared by the least significant difference (LSD) at 5% level of significance by using SPSS 23.0 (SPSS: An IBM Company, Chicago, IL, USA). Weed community composition was analyzed by using the principal component analysis (PCA) was performed by using CANOCO software [32].

3. Results

3.1. Variation of Soil Nutrients and Light Transmittance in Winter Wheat Field

Table 2 shows the variation of soil nutrients, and light transmittance in long-term diverse fertilizer management regimes. The soil organic matter and total N were lower in CK treatments and those receiving unbalanced fertilizers (N, NK and PK) than the other treatments ($P < 0.05$). The highest organic matter and total N contents were seen with MNPK treatments (Table 2). The available P content was the lowest in treatments given no phosphorus fertilizer (CK, NK and N), and the highest in MNPK treatment. The NP treatment had the lowest

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Table 2. Variation of soil nutrients concentration and light transmittance in winter wheat field.

Treatments	Soil Organic matter ($g \cdot kg^{-1}$)	Total N ($g \cdot kg^{-1}$)	Available P ($mg \cdot kg^{-1}$)	Available K ($mg \cdot kg^{-1}$)	Light transmittance (%)
CK	12.76^{d}	1.08^{d}	3.50^{c}	160.33^{g}	76^{a}
N	14.38^{cd}	0.88^{d}	3.45^{c}	170.14^{f}	73^{a}
NK	15.63^{c}	1.29^{c}	3.85^{c}	371.55^{b}	57^{b}
PK	15.47^{c}	1.01^{d}	27.98^{b}	278.39^{d}	58^{b}
NP	18.71^{b}	1.31^{b}	30.94^{b}	271.81^{e}	39^{bc}
NPK	18.49^{b}	1.45^{b}	28.86^{b}	305.16^{c}	11^{cd}
MNPK	27.82^{a}	1.76^{a}	115.36^{a}	419.80^{a}	12^{d}

Different letters within the same column indicate significant differences between treatments in winter wheat field ($P < 0.05$).

available K content, significantly lower than that of CK and N treatments; the highest soil-available K was observed with MNPK rather than NK. The application of NP or NPK also significantly increased the contents of these four parameters compared with applications of unbalanced fertilizers in winter wheat field.

The amount of light transmittance was significantly lower with MNPK treatment, while it was highest in CK and N treatments. With the NK and PK treatments, amount of light transmittance was similar but significantly lower than that of CK and N treatments ($P < 0.05$). With the NP and NPK treatments, light transmittance was significantly lower than that in unbalanced treatments, while it was relatively higher with treatments including organic manure under wheat field (Table 2).

3.2. Density and Species Composition of the Weed Communities

The long-term diverse fertilization treatments were greatly influenced the density of the weed communities (Figure 1). Weed density was substantially lower with balanced fertilizers treatments (NP, NPK and MNPK) compared with none (CK) or unbalanced fertilization (N, NK, PK) treatments in winter wheat field ($P < 0.05$). In contrast, total weed density was highest in the none (CK) or unbalanced fertilizers (N, NK, PK) treatments in winter wheat field (Figure 1).

Table 3 shows the differences in weed species that occurred with the various treatments. A total of 19 weed species from 10 families were also recorded in winter wheat field, of which six were perennial species, and other 13 species were annual (Table 3) in their life cycle. According to the functional group, the number of dicotyledonous weed species (15 spp.) was greater than that, of monocotyledonous (4 spp.). Asteraceae (4 spp.) was the most numerous family and followed by Brassicaceae, Poaceae and Euphorbiaceae were (3 spp.) respectively,

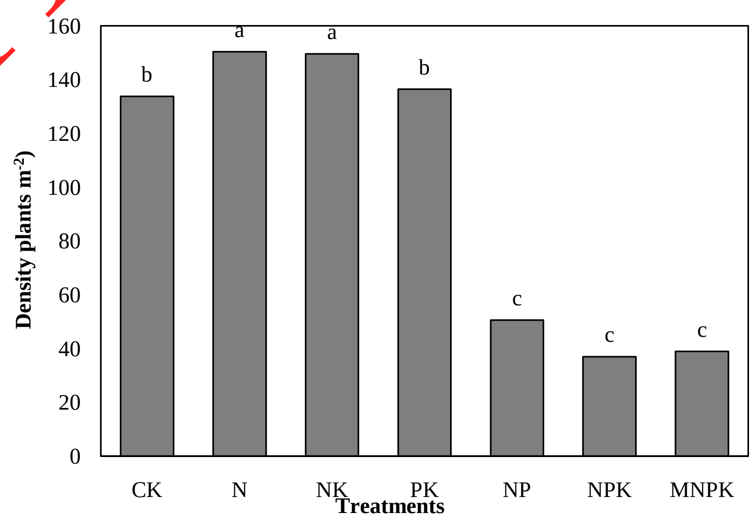

Figure 1. Density of weed communities (plants·m^{-2}) in different fertilizer management systems. Different lowercase letters on top of the bars represent significant difference between treatments at a 0.05 level (LSD test; $P < 0.05$).

Table 3. Weed densities in different fertilizer treatments.

No.	Species name	Density (plants·m^{-2})						
		CK	N	NK	PK	NP	NPK	MNPK
1	*Acalypha australis Linn.*	21.4	9.2	16	16.4	12	5.6	14.2
2	*Avena fatua*	2	1.4	3.2	0.4	1.6	1.6	1.8
3	*Brassica rapa.*	1.6	4	3.6	0.2	0.6	0.2	1.8
4	*Calystegia hederacea*	14	28.4	39.2	3.2	9.2	5.2	7.6
5	*Chenopodium glaucum Linn.*	1	5.8	1.6	0	11.2	8	5
6	*Coronilla varia Linn.*	5.6	0	1.4	1.4	0	0	0
7	*Cirsium arvense*	9.8	6.4	8.4	5.4	1.8	0	0.2
8	*Cyperus rotundus Linn*	0	0	0	3.8	1.4	0	0
9	*Cynodon dactylon*	3.4	12.4	0	25	0	0	0
10	*Echinochloa crus-galli*	0	0	0	0	0.2	0	0
11	*Erigeron annuus*	6	2.2	4.2	4.2	0	0	0.2
12	*Erysimum cheiranthoides*	0	0	0	0	0.4	0.6	0
13	*Eschenbachia japonica*	4	5	6.8	6	0	2	0.6
14	*Euphorbia helioscopia*	0	0	0	0	0	0	0.2
15	*Euphorbia humifusa*	6.2	7	8.4	4.6	2	5.2	2
16	*Lathyrus latifolius*	0	0	5.6	4.8	0	3.8	0.4
17	*Lactuca serriola L.*	5.4	4.6	0	1.4	0	0	0
18	*Setaria viridis (Linn.)*	53.4	64	51.2	50.2	10.2	4.8	5
19	*Veronica persica*	0	0	0	9.4	0	0	0

and other Convolvalaceae, Compositae, Gramineae , Fabaceae, and Plantaginaceae were one species respectively, in studied period. Under the experiment, the following six weed species; (*i.e., Acalypha australis Linn, Avena fatua, Brassica rapa, Calystegia hederacea, Chenopodium glaucum Linn, Euphorbia humifusa* and *Setaria viridis Linn*) had found in various treatments, while other 13 weed species were found in some of the treatments. The weed community composition also varied with fertilization regime, the most dominant species was perennial dicots, particularly *Calystegia hederacea* and *Setaria viridis Linn*, its highest density observed under different fertilization treatments. The annual dicots weed species; *Cirsium arvense, Erigeron annus, Eschenbachia japonica* and *Setaria viridis Linn* were most dominant in low fertility such as CK, N, NK and PK treatments (Table 3). In contrast, the annual dicots weed species, *Chenopodium glaucum Linn* which was most dominant in high fertility such as NP, NPK and MNPK treatments.

The classification results of weed species on the basis of morphotype and life cycle demonstrated that the monocotyledonous annual weeds had the highest proportion (36%) and dicotyledonous annual weed species had 35%, dicotyledonous perennial weed species had (23%) and monocotyledonous perennial had the lowest proportion (6%) respectively, among the life forms under different fertilizer management systems (Figure 2).

3.3. Influences of Diverse Fertilizer Management on the Biodiversity of the Weed Community

Fertilization also significantly influenced the species diversity (*H'*), evenness index (*E)* and richness (*R*) of the weed community (Table 4). The species diversity (*H'*) was highest in none (CK) or unbalanced fertilizers (N, NK, PK) treatments. The highest value of species richness (*R*) was also observed in PK treatment followed by NK, CK, N treatments. In contrast, the species diversity (*H'*) and richness (*R*) indices were slightly lower in fertilizer treatments those receiving balanced fertilization (NP, NPK and NPK integrated with organic manure) (Table 4). The evenness index (*E*) was no significant different among the treatments in rain-fed conditions.

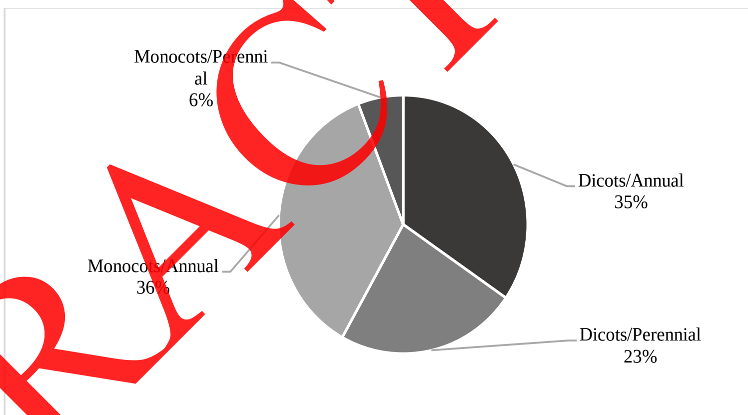

Figure 2. Comparison of the life forms of weed species present under fertilization management systems in winter wheat field.

Table 4. Diversity indices of weeds under different fertilizer management.

Treatments	Index		
	H'	E	R
CK	0.81^{ab}	0.17^{a}	2.09^{a}
N	0.80^{ab}	0.16^{a}	2.04^{a}
NK	0.80^{ab}	0.16^{a}	1.75^{ab}
PK	0.80^{ab}	0.16^{a}	1.72^{ab}
NP	0.68^{b}	0.18^{a}	1.57^{b}
NPK	0.71^{ab}	0.20^{a}	1.60^{b}
MNPK	0.64^{b}	0.18^{a}	1.54^{b}

Different letters within the same column indicate significant differences between treatments in winter wheat field (LSD test; $P > 0.05$). *H'*: Shannon's diversity index, *E*: Pielous's evenness index, D_{MG}: Margalef's richness index.

4. Discussions

Different fertilization treatments had significantly affected the soil organic matter and other soil nutrient parameters such as total N, available P and K (**Table 2**), thus exerting influences on density of weed species [33]. These results illustrated that the total weed density was low in nutrient-rich treatments (NPK closely followed by NP, MNPK), while it was high in unbalanced fertilizer managements (**Figure 1**). These results illustrated that the high soil nutrients contents promoted the growth of crops, thus decreased the light intensity available for weed growth (**Table 2** and **Figure 1**).

In plots receiving highest nutrients level was significantly suppressed on the growth of dominant weed species because of the increased competition of crop for light, water and nutrient sources. Therefore, biodiversity of weed species compositions in high nutrient inputs plots were significantly lower compared with the none or unbalanced fertilizer treatments (**Figure 1**). In agreement with the results of this study, Tang [34] who also described that, nutrient-rich treatment was more efficient at inhibiting the growth of weeds because of light radiation being restricted by crop. Moreover, the insufficiency of light intensity may also reduce germination of weed species [35]. However, Banks [17] indicated that total weed density was the lowest in no fertilizer (CK) treatment and the highest in balanced fertilizer treatment (NPK), some of the weed species was decreased in its density as fertility managements became more complete. It would be the influences of fertilizer applications on density of weed communities may be sensitive to regional weed species competition [36].

The dominant weed species, such as *Chorispora tenella and Euphorbia helioscopia* were occurred in plots no receiving the soil N and available P treatments in winter wheat field (**Table 3**), in contrast, when N and P are applied with together (NP, NPK and MNPK) treatments, those weed species were not as dominant species. 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 [37] 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.

Fertilization also significantly influenced the Shannon diversity, species evenness and richness indices of weed communities. Diversity indices of weed species were affected by density of weed and standing crop competition also. In this study, species richness and diversity indices were significantly lower in high soil fertility treatments. None and unbalanced fertilizer treatments resulted in significantly higher diversity indexes and richness (**Table 4**). Hillbig 1982 [38] and Ellenberg [39] also reported a similar result; nutrient poor-environments have a great diversity of weed species. In contrary, increase in high soil nutrient content evaluated the weed biodiversity level, while the community dominance was low [19].

5. Conclusion

Farm management practices, particularly the application of different fertilizers, can change the weed density and species composition. Our results showed that longer history of diverse fertilizer application altered nutrients concentrations, which exert influences on density of weed species. Balanced application of fertilizers (N and P) showed lowest weed density and reduced the weed species diversity, compared with an unbalanced fertilizer application, because of the competition for growth requirement resources between crop and weed. Therefore, both balanced fertilizer application and/or with organic amendments and diverse crop rotation strategies should be incorporated in sustainable crop production systems.

Conflicts of Interest

There are no conflicts of interest in present study.

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