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Scopus Compendex and Geobase Elsevier,
Geo-Ref Information Services-USA, List B of Scientific
Journals, Poland, Directory of Research Journals

International Journal of Earth Sciences and Engineering

www.cafetinnova.org

ISSN 0974-5904, Volume 09, No. 06

December2016,P.P.2409-2418

Vegetation Restoration through Laying Cornstalks on a Bare Sodic Patch in Songnen Plain

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Abstract: Grassland salinization and sodification has become a global concerning issue in recent years. Many bare sodic patches have appeared after grassland degeneration caused by soil salinization in Songnen plain, which inhibits growth and development of forage grass. In order to searching for an effective method to restore vegetation on sodic patches, a 3-year study was carried out to test whether laying cornstalks could promote vegetation restoration on bare sodic patches. The study contained 3 cornstalk amount, namely, 1 (T1), 2 (T2) and 3 (T3), and 4 directions, namely, east-west (EW), south-north (SN), northeast-southwest (NESW), southeast-northwest (SENW), respectively. Compared with spot without cornstalk laying (CK), soil organic carbon (SOC) was not significantly altered by cornstalk ($p>0.05$). EC in 2013 and pH in 2014 showed significantly ($p<0.05$) decrease compared with CK for all the 3 treatments, but no significant differences ($p>0.05$) were observed among T1, T2 and T3. Application of cornstalks promoted vegetation restoration than CK in the 3 years, but amount and direction of cornstalk didn't have significant effect on the indices (aboveground biomass, community height, community coverage and specie number) except for community coverage in 2013 ($p>0.05$) when CK was excluded. Average aboveground biomass, community height and specie number presented highly variability among years. Laying cornstalk is effective in revegetation on bare sodic patches, regardless of laying amount and direction.

Keywords: *laying cornstalk; bare sodic patches; amounts; directions*

1. Introduction

Throughout the world, soil salinization, which is one kind of most serious land degradation, has become a major concern (Liang et al., 2005; Yuan et al., 2007). It always occurred in arid and semiarid regions (Yuan et al., 2007). About 10% of the total dry land was affected by salinization (Szbolcs, 1989), and the situation aggravates in many parts of the world (Pannell and Ewing, 2006). Salinity can result in soil degradation and severely decrease land potentially production (Keren, 2000), constraining the sustainable development of agriculture and pasture, subsequently causes economic, social and ecological problems. As a result, amelioration and reclamation of saline soil have become critical and urgent targets for sustainable development of humanity.

Straw is a promising materials for amelioration of saline soils (Bezborodov et al., 2010; Deng et al., 2003; Pang et al., 2010). The application of straw (mainly in the form of straw mulching) can shade the soil, weaken the surface evaporation, increase infiltration as well as soil water content, reduce the salt accumulation in the topsoil (Maurya and Lal, 1981; Ji and Unger, 2001; Ghosh et al., 2006; Mulumba and Lal, 2008; Pang et al., 2010). Meanwhile, the decomposition of straw can provided soil organic matter, improve soil porosity and aeration (Lal and Stewart, 1995; Duiker and Lal, 1999; Tejada et al., 2008), which favors the infiltration of salt.

Songnen plain, which locates in the central part of northeastern China, is one of the three saline-sodic soil distributing area in the world (Deng et al., 2006; Wang et al., 2009). It is also an important region for grazing and farming in the north China. However, in recent years, owing to irrational utilization resulted from population pressure, soil salinization and degradation of the grassland in Songnen plain has become rather serious, with about 70% of grassland being salinized, and it increases at a rate of 1.5-2% each year (Zheng and Li, 1993; Shang et al., 2003). In some place, sodic patches widely distribute as a result of grassland degenerating. The deteriorated physical-chemical properties of the surface soil on the sodic patch impose negative effect on the growth and development of plants (Zheng and Li 1990; Gao et al.1996; Wu and Li 2003), causing losses of forage grass production ,which further inhibits sustainable development of economy, ecosystem and society (Liu et al.,2009). As a result, the reclamation and revegetation of those sodic patches is very important.

Seed bank and safe microsite are two critical factors in revegetation. In deteriorated habitats such as sodic patches, soil seed banks are important factors for revegetation (Cummings et al. 2005). The shortage of seed bank in the soil of sodic patches constraints the restoration of vegetation. However, large amount of seeds move laterally across the surface of sodic patches, which can provide abundant seed sources for vegetation restoration if contained effectively (Wu et al., 2005). Meanwhile, a safe microsite can also help enhance germination rate of seeds and survive rate of seedlings, especially in some severely degraded habitats (Harper et al., 1961; Dalling & Hubbell, 2002; Elmarsdottir et al., 2003). So when planning vegetation restoration, it is important for successfully create safe microsite on bare sodic patches.

In Songnen plain, where the corn is one of the most widely planted crops, the straw from corn (cornstalk) is very abundant, which provides enough material basis for revegetation on sodic patches. Several studies about revegetation with application of cornstalks have been conducted. Among them, inserting cornstalks is the most common studied method (Wu et al., 2001; He et al., 2004 and 2005; Jiang et al., 2010). It can not only help trap the seed movement passing the surface of sodic patches as seed source, but also create a safe microsite by improving the soil property in local scale for the restoration of the initial vegetation. Furthermore, the initial vegetation will accelerate restoration of the subsequent vegetation by providing more seed sources as well as safer microsites (Jiang et al., 2010). Besides inserting cornstalks, we suppose laying cornstalk on the sodic patches can also trap seed movement for vegetation restoration. As the amount of cornstalk increase, the restoration effect may also be better. Simultaneously, we assume the main driven factors of seed movement is wind, so cornstalks leading to different directions may vary in capturing seeds, with optimal laying direction vertical to the prevalent wind.

Based on the information above, we design a study to examine the effect of laying cornstalk on vegetation restoration on sodic patches. The objectives of the study are: 1) determining the soil property under different amount of cornstalks, 2) evaluating the vegetation restoration effect under application of cornstalks, 3) discussing the optimal amount and laying direction of cornstalks for revegetation.

2. Material and Method

2.1 Site description

The study site locates in grassland farming ecological research station of Changling, Academy of Science of China, Jilin Province (44°33′ N, 123°31′ E), which covers an area of about 300ha. The study area is relatively flat and its elevation is about 145 m above sea level. The climate is characterized by a temperate, semi-arid continental monsoon climate, with annual average air temperature between 4.9℃ to 6.4℃. Precipitation varies from 300 mm to 450 mm greatly between years with 70-80% of total precipitation occurs between July and September. The pan evaporation is approximately 1600 mm. Main soil types in this area are chernozem, aeolian sandy soil and saline-sodic soil, with pH of the soil ranging from 7.5 to 10. Dominant specie in grassland are *Leymus chinensis* and *Chloris virgata*. Bare sodic patches commonly distribute in spots with severely high soil pH and salt content. Only sporadic *Suaeda spp*. or even no vegetation can be found on sodic patches. The salts in the soil of sodic patches are mainly $NaHCO_3$ and Na_2CO_3. The soil pH can reach up to 10.6-10.7, with EC ranging from 1100 to 1600 $\mu s.cm^{-1}$. Corn and sunflower are two widely planted crops in this region, and cornstalks are abundant as an agronomy byproduct.

2.2. Experiment design

The study was carried out from 2011 to 2014 on a selected sodic patch with an area of approximately 1ha, which consisted of three treatments. In October of 2011, 8 cornstalk units, each of which consisted of 5 cornstalks, were laid on the ground in each treatment, with 8 cornstalks units leading to 4 directions, namely, east-west (EW), south-north (SN), northeast-southwest (NESW), southeast-northwest (SENW). Subsequent to laying cornstalks on the ground, those cornstalks were fixed on the surface of the sodic patch by inserting several sticks on both sides in order to prevent them from relocation by wind. The cornstalk unit amounts in each direction were 1, 2 and 3 for the three treatments, respectively, which were referred as T1, T2 and T3, respectively. For treatment T2 and T3, the cornstalks in the same direction were laid side by side and close to each other. Each treatment included 3 replications.

2.3 Plant sampling and measurement

In late August of 2012-2014, the vegetation restored was investigated and sampled. In 2012, five sampling plots with a size of $0.3\times1m^2$ were set up along the cornstalks for each treatment, with cornstalks being the central axis of each plot. In 2013 and 2014, the sampling tactic evolved: in each treatment, five sampling plots with the same size as that in 2012 were selected along the cornstalks in each direction to evaluate the vegetation restoration in different directions, namely, 20 plots per treatment. Species number (SN), community height (CH), community coverage (CC) in the plots was investigated, as well as density, height and coverage of each species. Subsequent to that, the plants in each sampling plot were harvested at the ground level with separation of each species. Those plants harvested were oven-dried at 65℃ to constant weight and weighed to obtain aboveground biomass (AB). The aboveground biomass was converted to biomass per m^2.

Also, in 2012, height, canopy range and individual tiller amount (ITA) of *C.virgata* were also investigated to evaluate the growth of *C.virgata*, a representative specie in the vegetation restored. In 2013, ITA was excluded for the poor amount, and seed production of *C.virgata* was investigated: 15 spikelets were randomly selected for investigating the mean seed amount in individual spikelet, then total seed product was calculated by average seed amount per spikelet multiplying total spikelet amount in one plot. In 2014, due to rather few *C.virgata* appearing in the vegetation restored, the investigation of those indices of *C.virgata* was not carried out.

2.4 Soil sampling and determination

In late September of 2013 and 2014, soil sampling was conducted. Three replicated samples were collected immediately close to cornstalks in every replication of each treatment. The soil in the spot without cornstalk laying was also sampled as CK. Soil samples were obtained from 0-50cm depth at an interval of 10cm with a hand auger (inner diameter of 3cm). The three replicated soil samples from the same layer were mixed as one representative sample for each replication of each treatment. Soil samples obtained were air-dried, ground, then passed through 2-mm sieve for determination of soil pH and electricity conductivity (EC). In 2013, each soil sample was separated into two subsamples, with one passed through 0.5mm-sieve to measure soil organic carbon (SOC), besides the determination of pH and EC.

Soil pH and EC were determined in soil: water=1:5 suspension with pH and EC meter (PHS-3C and DDS-307, respectively, Shanghai Precise Scientific Instrument Company). SOC was measured with KCr_2O_7 oxidation method according to Walkley and Black (1934).

2.5 Data analysis

To investigate whether cornstalk amount and laying direction have significant effects on indices indicating vegetation restoration, Multivariable ANOVA was applied. Effect of cornstalk amount on soil properties, such as pH, EC and SOC, was tested with one-way ANOVA. Significant differences between treatments were examined with LSD method. The results were presented in the form of Mean ±SD.

3. Results

3.1 SOC

The laying of cornstalk and depth didn't significantly affect SOC ($p>0.05$). Also, not obvious trend of SOC was observed among different treatments as well as different depth (Table 1).

Table1: *SOC ($g.kg^{-1}$) for different treatments and depth in 2013. Capital letters indicate significant differences among treatments in given depth ($p<0.05$), small letters indicate significant differences among depth in given treatment ($p<0.05$). The meaning of letters in the tables below is the same.*

Depth (cm)	CK	T1	T2	T3
0-10	2.93±1.08	2.66±0.4	2.81±1.38	1.99±1.38
10-20	2.86±0.9	2±0.45	3.54±1.93	1.86±0.74
20-30	2.21±0.55	2.43±0.97	1.62±0.47	2.1±2.48
30-40	1.26±1.82B	1.4±1.22AB	3.61±0.56A	1.24±0.35B
40-50	1.44±1.01	2.73±1.22	2.13±0.53	1.75±1.34

3.2 pH and EC

In general, the application of cornstalks decreased pH and EC to some extent. In 2013, EC was significantly decreased ($p<0.05$) compared with that in CK, but there were no significant differences between T1, T2 and T3 ($p>0.05$). However, application of cornstalks didn't significantly affected soil pH ($p>0.05$), and there was not a regular trend among CK and other treatments. In 2014, it was just opposite, namely, pH was significantly ($p<0.05$) affected by cornstalk laying, with significant differences ($p<0.05$) between CK and cornstalk laying. EC didn't respond significantly to cornstalk addition ($p>0.05$), although slightly decrease was observed between CK and other treatments (Table 2.1-2.4).

Table2.1: *pH for different treatments and depth in 2013.*

Depth (cm)	CK	T1	T2	T3
0-10	10.7±0.03	10.69±0.07b	10.7±0.12	10.7±0.25
10-20	10.71±0.03	10.76±0.05ab	10.79±0.08	10.78±0.06
20-30	10.69±0.04	10.82±0.09a	10.73±0.22	10.66±0.16
30-40	10.66±0.04	10.74±0.08ab	10.66±0.11	10.77±0.10
40-50	10.63±0.06	10.72±0.04ab	10.76±0.12	10.5±0.44

Table2.2: *pH for different treatments and depth in 2014.*

Depth (cm)	CK	T1	T2	T3
0-10	10.82±0.09A	10.47±0.03bB	10.56±0.28AB	10.52±0.12B
10-20	10.83±0.06A	10.49±0.12Bab	10.5±0.13B	10.47±0.12B
20-30	10.85±0.04A	10. ±0.1Bab	10.66±0.15 AB	10.45±0.1C
30-40	10.83±.09A	10.61±0.07Ba	10.61±0.11B	10.54±0.06B
40-50	10.84±0.05A	10.6±0.04 Bab	10.57±0.04B	10.4±0.06C

Table2.3: *EC ($\mu s.cm^{-1}$) for different treatments and depth in 2013.*

Depth (cm)	CK	T1	T2	T3
0-10	1065±221Ab	557±34Bb	726±163B	748±206ABb
10-20	1326±230Aab	701±98Bb	751±168B	933±313ABab
20-30	1487±268Aab	943±60Bab	934±214B	985±364Bab
30-40	1646±290Aa	1044±246Ba	839±254B	870±225Bab
40-50	1565±293Aa	1038±162Ba	936±205B	1254±223ABa

Table2.4: *EC for different treatments and depth in 2014.*

Depth (cm)	CK	T1	T2	T3
0-10	971±79	785±153	774±263b	884±236
10-20	1366±296	860±264	873±205b	1260±341
20-30	1272±214	1068±365	1037±100ab	1339±427
30-40	1275±184	1053±268	1237±220 a	1241±333
40-50	1246±258	1019±159	1106±157ab	1449±369

3.3 Vegetation

3.3.1 Species and community composition

The community is mainly made up of salt-tolerant plants with slight amount of helophytes, such as

Suaeda Salsa, *C.virgata*, *P.tenuiflora*, *Echinochloa crusgalli*, *Crypsis aculeata*, etc. Species and community showed largely variation among years. The detail was shown in Table 3.

Table 3: *All species, dominant species, specie number per quadrat for the restored vegetation in 2012-2014.*

Year	All Species	Two Dominant Species for each Treatment			Specie Number in One Quadrat	Average Specie Number in One Quadrat
		T1	T2	T3		
2012	*Chloris virgata*, *Echinochloa crusgalli*, *Puccinelia tenuiflora*, *Suaeda salsa*, *Crypsis aculeata* (5)	*C.virgata* *E.crusgalli*	*C.virgata* *E.crusgalli*	*C.Virgata* *E.crusgalli*	2-4	2.89
2013	*C.virgata*, *E.crusgalli*, *P. tenuiflora*, *S.salsa*, *C. aculeata*, *Phragmites australis*, *Polygonum aviculare*, *Scirpus planiculmis* (8)	*C.virgata* *E.crusgalli*	*C.virgata* *E.crusgalli*	*S.salsa* *C.virgata*	1-6	2.31
2014	*C.virgata*, *E.crusgalli*, *P.tenulflora*, *P.aviculare*, *P.australis* (5)	*E.crusgalli* *P.tenuiflora*	*P.tenuiflora* *E.crusgalli*	*P.tenuiflora* *E.crusgalli*	1-3	1.43

Table 4:*Two-way ANOVA for effects of cornstalk amount (A), laying direction (D) and their interaction on aboveground biomass (AB), community height (CH), community coverage (CC) and specie number of the restored vegetation. Only p value is present. Significance level is 0.05. And ns means no significance.*

	2012				2013				2014			
	AB	CH	CC	SN	AB	CH	CC	SN	AB	CH	CC	SN
A	ns	ns	ns	ns	ns	ns	0.009	ns	ns	ns	ns	ns
D	-	-	-	-	ns	ns	ns	ns	ns	ns	ns	ns
A*D	-	-	-	-	ns	ns	ns	ns	ns	ns	ns	ns

3.3.2 CH, CC and AB

In 2012, CH, CC and AB presented inconsistent trend as the amount of cornstalk applied increased. CH increased with cornstalk amount; the maximum of CC appeared in T2, and the minimum in T1. However, AB decreased with cornstalk amount increased (Fig.1). However, the cornstalk amount didn't have significant effect on CH, CC and AB ($p>0.05$). Also, no significant differences ($p>0.05$) were detected between treatments in CH, CC and AB (Table 4).

In 2013, totally speaking, the trend of average CC and AB among different treatments was similar, the average of the 2 indices above in T2 was the largest, and the minimum was observed in T3. Whereas, CH was highest in T1 (Table 4). However, CH, CC and AB of different directions in each treatment didn't presented consistent and obvious trend (Fig.2). Only CC was significantly affected ($p<0.05$) by cornstalk amount (Table 4).

In 2014, the average of those indices was in the order of T2>T1>T3, which was the same as that in 2013, except for CH with maximum in T1 (Table 4). In each treatment, the trend of the indices among different directions was still not obvious, just as that in 2013 (Fig.3). Neither amount of cornstalks nor laying direction had significant effect on the three items ($p>0.05$, Table 4).

3.3.3 Height, canopy range, individual tiller amount (ITA) and seed production of *C. virgata*

As shown in fig.1, in 2012, maximum of plant height appeared in T2, and that in T1 and T3 was similar. Canopy range decreased with the increasing cornstalk amount, but ITA increased with cornstalk amount. Still, plant height, canopy range and ITA of *C.virgata* were not significantly affected by application of cornstalks of different amount ($p>0.05$), simultaneously, didn't present significant differences between all treatments ($p>0.05$).

In 2013, the average of above indices and seed production were all consistently largest in T2. Then followed by T1 and T3. However, for all the treatment, the 3 indices didn't present consistent trend among different directions (Fig.2). Still, neither the cornstalk amount nor laying directions had significant effect ($p>0.05$) on those indices above.

3.3.4 Vegetation dynamic among years

Average AB, CH and SN were all significantly affected ($p<0.05$) by years. However, CH and SN for all treatments were significantly affected, but AB only in T3, which showed significant decrease between 2014 and 2012 ($p<0.05$, Table 5). In other two treatments, though AB still decreased from 2012 to 2014, no significant differences were detected among years ($p>0.05$). For CH, in all treatments, it decreased significantly ($p<0.05$) from 2012 to 2014 (Table 5). And significant differences existed between any two years among the three ($p<0.05$). SN also decreased significantly from 2012 to 2014 ($p<0.05$, Table 5), and SN in 2014 was consistently significantly different from that in 2012 for all the three treatments ($p<0.05$).

4. Discussion

As mentioned in the introduction, the main two problems which limit restoration of vegetation on sodic patches are deteriorated soil property in the surface and lack of seeds and other propagullums (Wu et al., 2005). Although the poor soil condition is not favorable for most plants, the seeds of some plants with high salt-tolerance, such as *Suaeda spp*., can still germinate and their seedlings can grow normally (He et al., 2004). So the shortage of the soil seed banks on sodic patches is the primary constraint for revegetation rather than bad soil condition. However, considering the abundant seed movement passing through the surface of sodic patches in Songnen plain, with a high proportion of seeds of salt-tolerant species, on the sodic patches surface (Wu et al., 2005), we can design a method to effectively trap seed movement as seed sources for restoration, such as inserting cornstalks, as well as laying cornstalks in our study.

Compared with CK where there was almost no vegetation, the position with cornstalk laying was covered by restored vegetation. In general, the cornstalk laying on ground could provide a good media for trapping the seed movement passing through the surface of sodic patch, which provided abundant seed source for vegetation restoration (Jiang et al., 2010). Meanwhile, at the place where cornstalks contacted with soil, the cornstalks were decomposed by microorganism, releasing some organic acid and other nutrients to soil (Wu et al., 2001; He et al., 2004 and 2005). As a result, the physical-chemical properties of the soil next to the cornstalks were improved, with decreased pH and EC as well as increased organic matter and other nutrients, which provided a safe microsite for the germination of the trapped seeds and survive of the seedlings.

So the vegetation mainly concentrated along the cornstalks rather than on the bare sodic soil. However, due to low activity of microbial in the sodic soil, the decomposition was relatively slow, and the scope affected by cornstalks was small, which was only limited to a narrow site close to cornstalks. So the vegetation restored almost distributed immediately next to cornstalks, within a distance of 10cm from the cornstalks, with only few individuals outside this scope.

Though laying cornstalks effectively promoted restoration of vegetation compared with CK, the amount and directions of laying didn't impose significant effect on the vegetation restored ($p>0.05$). The reason may be that the increasing amount of cornstalks didn't increase the ability of trapping seed movement and alter soil properties enough, such as SOC, pH and EC. Simultaneously, the condition of trapping seed movements for cornstalks with different directions was similar, indicating the frequency of wind with different directions was also similar, or distribution of seeds along cornstalks was also driven by other factors besides wind.

Among the seed movement, the seeds of *C.virgata* occupied the most proportion (Wu et al., 2005). That was probably attributed to their large seed production and highly spreading ability. So, in the year 2012 and 2013, the most predominant specie in the vegetation was *C.virgata*, with several other salt-tolerant species. However, in 2014, the composition of the vegetation varied significantly: *E.crusgall*i, which mainly grew in relatively wet habitats, became the most predominant specie, with aboveground biomass of *C.virgata* reducing sharply. That may be due to the variation of climate or other factors. In that year, though a severe drought occurred in July and August, a strong rainfall appeared in mid-June, the time when most seedlings of *C.virgata* emerged, causing waterlogging for a long time. The waterlogging inhibited germination of seeds and seedling growth of *C.virgata*. However, the seedling of *E.crusgalli* probably has stronger tolerance to waterlogging than that of *C.virgata*, because *E.crusgalli* distributes in habitats with more moisture compared with *C.virgata* (Yang et al., 2013). Although a part of individuals of *E.crusgalli* died in the subsequent severe drought period which almost lasted for two months, that specie was still the most dominant since few seedling of *C.virgata* emerged and established during the drought.

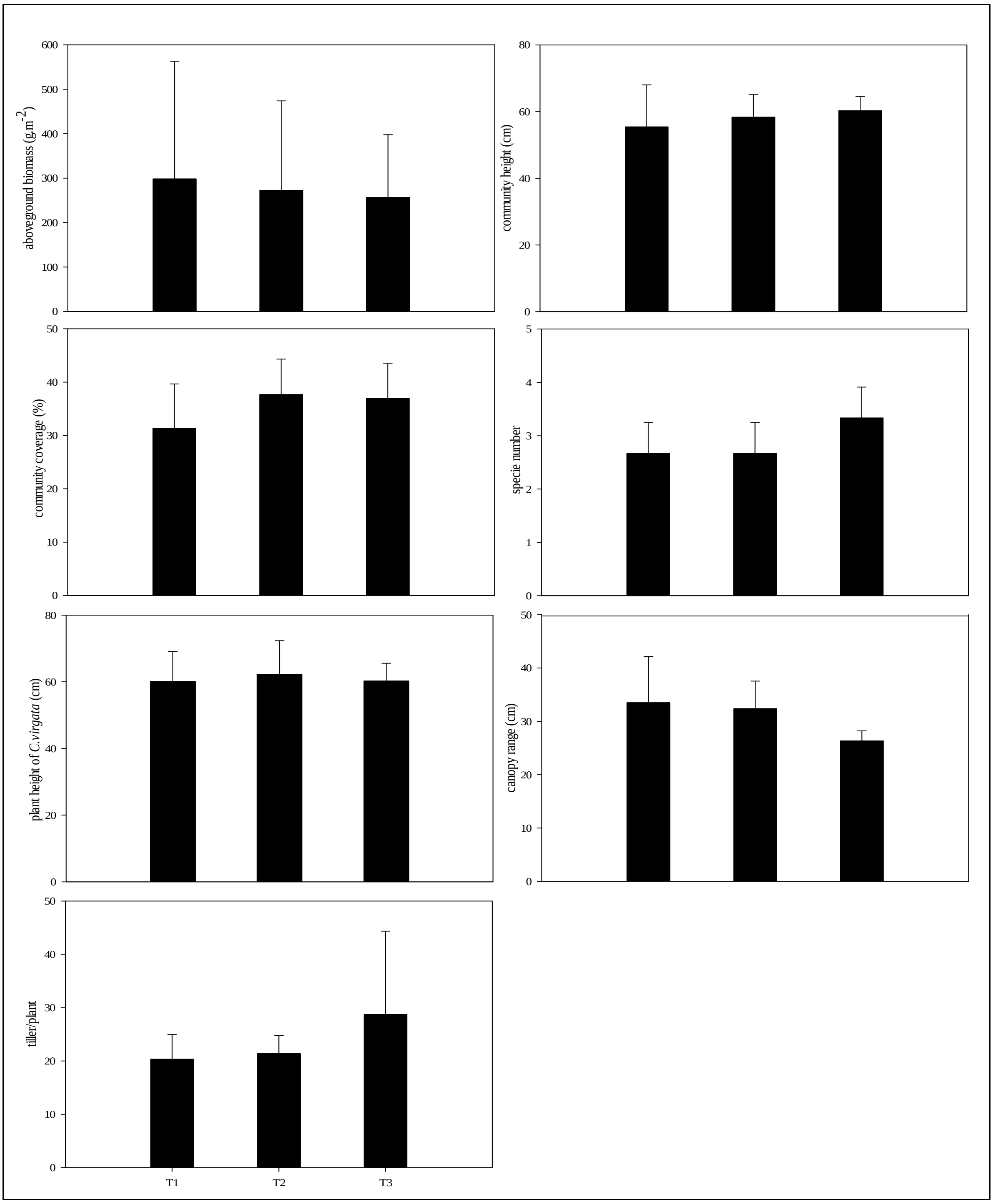

***Fig*.1** *Aboveground biomass a), height b), coverage c) and specie number d) of the community as well as plant height e), canopy range f) and tillers of individual plant g) for C. virgata among different cornstalk amounts in 2012.*

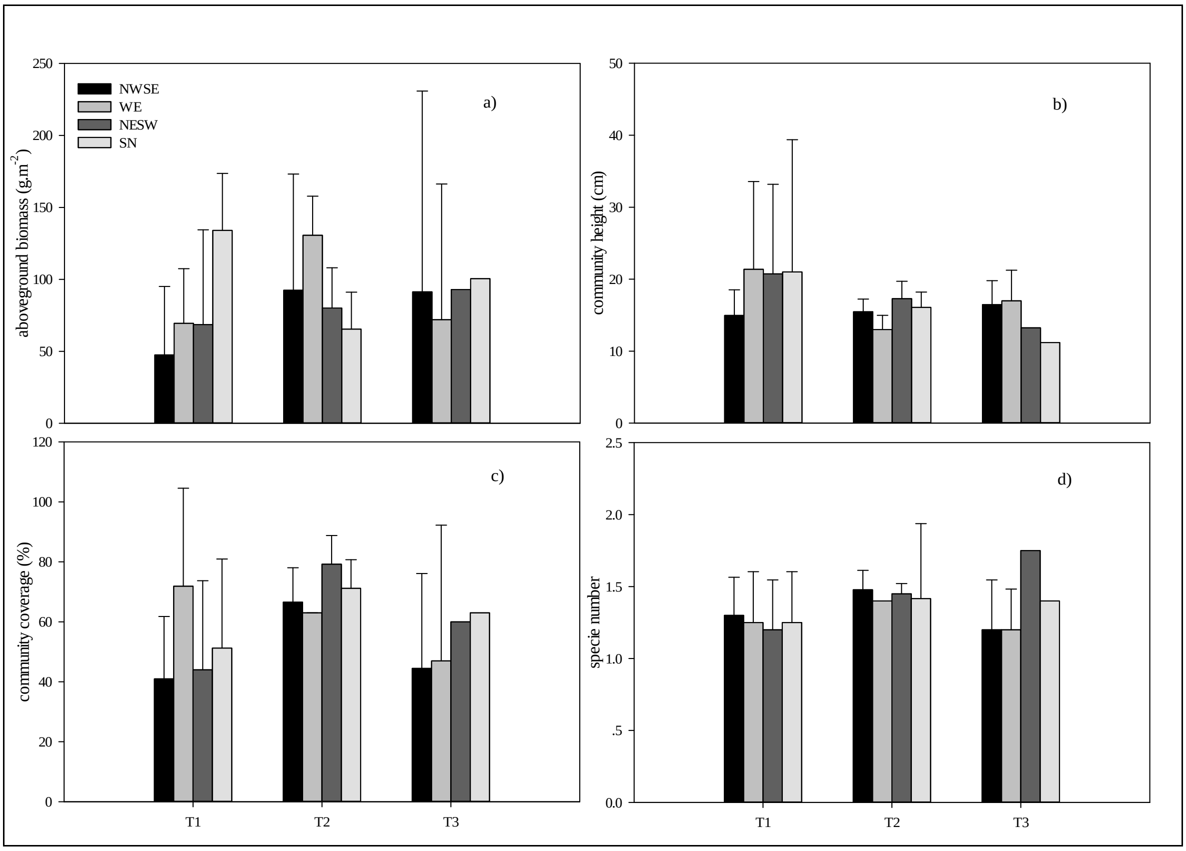

Fig. 3 *Aboveground biomass a), height b), coverage c) and specie number d) of the community among different cornstalk amounts and laying directions in 2014.*

Table 5: *Average aboveground biomass, community height, community coverage and specie number for different treatments and years*

Year	Aboveground Biomass (g.m^{-2})			Community Height (cm)		
	T1	T2	T3	T1	T2	T3
2012	298.38±264.72	272.72±201.20	256.62±141.22a	55.42±12.63a	58.35±6.85a	60.28±4.23a
2013	200.05±24.21	239.62±38.84	171.48±66.31ab	36.74±1.72b	34.77±2.24b	32.84±4.50b
2014	63.99±50.08	79.37±49.91	53.98±79.86b	18.24±9.68c	15.73±1.55c	16.99±3.63c

Year	Community Coverage (%)			Specie Number		
	T1	T2	T3	T1	T2	T3
2012	31.33±8.33	37.67±6.66c	37.00±6.56	2.67±0.58a	2.67±0.58a	3.33±0.58a
2013	40.60±11.26AB	53.22±10.25Ab	28.95±12.23B	2.37±0.16a	2.32±0.50a	2.23±0.60b
2014	44.06±28.01	69.39±3.34a	39.00±27.56	1.21±0.19b	1.40±0.18b	1.18±0.31c

Other vegetation restoration approaches on sodic patches with cornstalks, as well as cornstalks inserting and levelly burying, have been researched in previous studies (Wu et al., 2002; He et al., 2004 and 2005; Jiang et al., 2010). Most research was focus on inserting cornstalks. According to their studies, inserting cornstalks, either alone or combined with sowing seeds of some salt-tolerant species, could effectively promote revegetation on the sodic patches. Without sowing seeds, the specie in the vegetation naturally restored was dominant by *C.virgata*. The sown perennial plants, such as *L.chinensis* and *P.tenuiflora*, could survive and establish with inserting cornstalks, providing more seed and accelerate revegetation (Jiang et al., 2010). However, although the aboveground and coverage was close to, or even exceeded those of a grassland in good condition in our and their research, the specie and community composition still presented rather significant differences compared with those for good grassland. So it would require more time to revegetate sodic patches to good grassland if the composition and specie interaction was taken into consideration.

Jiang et al. (2010) have reported that the initial vegetation could accelerate the restoration of subsequent vegetation by providing more seed source and improving soil condition. In that study, although aboveground biomass and other indices of the initial vegetation was rather low, they increased significantly in subsequent years. However, in our study, the aboveground biomass, community height and specie number all significantly decreased from 2012 to 2014. That could be explained by precipitation. In 2012, with the most abundant rainfall in the 3 years, the salt in the surface soil was leached into deep layer, creating a suitable environment for plant growth. However, a severe drought occurred in 2014, negatively affected the growth of plant.

In our study, SOC was not significantly increased ($p>0.05$) by the application of cornstalk, and only EC in 2013 and pH in 2014 decreased significantly ($p<0.05$) under treatments with cornstalks. However, other studies about cornstalk inserting and levelly burying indicated cornstalks could significantly increase soil organic matter, decrease pH and EC (Wu et al., 2001; He et al., 2004). The difference of improvement for soil properties might result from the specific site and method. For inserting and levelly burying cornstalks, the proportion of cornstalks contacting with soil was larger than that for laying cornstalks, so the cornstalks might decompose rapider, and improve the soil properties more effective. However, although soil properties was significantly improved compared with that of CK in those studies, soil condition after revegetation was still rather poor compared with that in a good grassland due to high pH (Jiang , unpublished) and low soil organic matter (Wu et al., 2001), even in 6 years after onset of the study (Jiang, unpublished). The restoration of soil properties required much longer time compared with restoration of vegetation.

Other approaches for revegetation, such as the application of litter, sand and gypsum, have proved to be effective for revegetation in severely degraded grassland to some extent (Li and Zheng, 1997; Guo et al., 1998). However, those methods can’t be used in large scale due to their high cost. Relatively, the cost of revegetation with cornstalks is very cheap, because cornstalk is quite available and inexpensive in our research area. Compared with other methods, revegetation through cornstalks can be applied in larger scale and to the degraded habitats with similar condition to our study area, because it sufficiently utilizes diverse seed sources and provides suitable microsite by agricultural byproducts with low cost.

5. Conclusion

Many other researches about revegetation by applying cornstalks to bare sodic patches have obtained significant effect, either by inserting or level burying the cornstalks. In our study, laying cornstalks on sodic patches effectively promoted vegetation restoration, although no significant differences were observed among different laying amounts and directions. As well, the restored vegetation composition and the trend of indicators for vegetation restoration among treatments also varied among years. So the effect of laying cornstalks on revegetation was complicated and impacted by climate. As a result, this method still needs much research for better understanding. However, this method has a low cost, because cornstalk was a rather abundant byproduct in this region, making it possible for wide application. With a deeper understanding of this approach, application of laying cornstalks would be a promising approach for vegetation restoration on bare sodic patches in the future, and would be used in a widespread scale.

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