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EFFECT OF MAIZE-SOYBEAN INTERCROPPING AND HAND WEEDING ON WEED CONTROL

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ABSTRACT

The aim of our study was to investigate interactive effects of maize-soybean intercropping and hand weeding on the growth of weeds. The field experiments were laid out in a split-plot design with three replications. The main plots were three weeding regimes: No-weeding (NW), hand-weeding once at 3-4 leaf stage of maize (HW1) and hand-weeding twice at 3-4 leaf and 8-9 leaf stages of maize (HW2). The sub-plots were different intercropping patterns: Mo (sole maize), M1 (maize + 1 soybean row in the inter-row of maize), M2 (maize + soybean grown in the same row with maize) in spring-summer season. In winter season, M2 was replaced by M3 (maize + 2 soybean rows in the inter-row of maize). Weed density and biomass were determined within three random quadrats (0.25 m^2) per plot at three growing stages of maize: 3-4 leaf stage (S1), 8-9 leaf stage (S2) and 13-14 leaf stage (S3). The results showed that the intercropping and hand weeding sharply suppressed weed growth. In the experiments, goosegrass (*Eleusine indica)* was the most prevalent weed with a higher density and a dry matter; however, its growth was strongly reduced by maize-soybean intercropping and hand weeding. Double hand-weeding significantly reduced weed density and biomass compared with single hand weeding. Even though intercropping positively suppressed weed growth, the study confirmed the importance of hand weeding in weed control efficiency. Our results suggested that under cultivation condition without herbicide usage, maize-soybean intercropping should be combined with 2 hand-weeding.

Keywords: Goosegrass, intercropping, hand weeding, weed.

Ảnh hưởng của trồng xen ngô - đậu tương và biện pháp làm cỏ thủ công đến kiểm soát cỏ dại

TÓM TẮT

Nghiên cứu này nhằm đánh giá ảnh hưởng của trồng xen ngô - đậu tương và biện pháp làm cỏ thủ công đến sinh trưởng của cỏ dại. Thí nghiệm đồng ruộng được bố trí theo kiểu Split-plot với ba lần nhắc lại. Ô lớn được bố trí tương ứng với số lần làm cỏ thủ công: Không làm cỏ (NW), làm cỏ một lần ở giai đoạn ngô 3-4 lá (HW1), làm cỏ hai lần ở giai đoạn ngô 3-4 lá và 8-9 lá (HW2). Ô nhỏ được bố trí tương ứng với kỹ thuật trồng xen: M0 (ngô trồng thuần), M1 (trồng xen 1 hàng đậu giữa hai hàng ngô), M2 (trồng đậu trên cùng hàng với ngô) ở vụ xuân hè, hoặc M3 (trồng hai hàng đậu giữa hai hàng ngô) ở vụ đông. Mật độ và chất khô của cỏ dại cũng như cây mọc lẫn được đo đếm trong ba khung điều tra ngẫu nhiên (0,25 m^2) cho mỗi ô thí nghiệm ở ba thời kỳ: ngô 3-4 lá (S1), 8-9 lá (S2) và 13-14 lá (S3). Kết quả chỉ ra rằng trồng xen và làm cỏ thủ công đều làm giảm đáng kể sinh trưởng của cỏ dại. Trong các thí nghiệm này, cỏ mần trầu (*Eleusine indica)* là loài cỏ chiếm ưu thế nhất trên ruộng ngô với mật độ và khối lượng chất khô cao, tuy nhiên sinh trưởng của loài cỏ này bị giảm đáng kể bởi trồng xen và làm cỏ thủ công. Làm cỏ hai lần làm giảm mật độ và sinh khối cỏ nhiều hơn so với làm cỏ một lần. Nghiên cứu này một lần nữa xác nhận tầm quan trọng của biện pháp cỏ thủ công trong việc kiểm soát cỏ dại hiệu quả. Ngô-đậu tương trồng xen nên được kết hợp với hai lần làm cỏ thủ công khi không sử dụng thuốc trừ cỏ.

Từ khóa: Cỏ dại, cỏ mần trầu, làm cỏ thủ công, trồng xen.

1. INTRODUCTION

In order to reduce the loss of crop yield by weeds, herbicides have been applied for a long time and becoming an attractive solution for weeds control over the world. However, their widespread use causes adverse effects on the environment, ecosystem, crops, human health, and beneficial insects and leads to resistance of weeds to common types of herbicide (Kimmins, 1975; Altieriand Lebman, 1986; Rico-Martinez et al., 2012; Kughur, 2012).

Intercropping has proven its benefits to control weed in crop production by reducing growth and development of weed (Liebman and Dyck, 1993; Poggio, 2005; Sharma and Banik, 2013). Several studies have demonstrated advantages of maize and legume intercropping in weed suppression and increasing the yield of crops. In a maize-soybean intercropping experiment, Shah et al., (2011) showed a significant decrease in the dry matter of weed under intercropping condition compared to sole crop as a control treatment. Since weed growth was suppressed by intercropping, it allowed reducing the dependency on herbicide in crop production (Carruthers et al., 1998, 2000; Banick et al., 2006). Although intercropping reduced weed growth, additional weeding was necessary to control weeds efficiently and ensure high yield of crops (Moody, 1977; Carruthers et al., 1998; Shetty and Rao, 1981). Also, Khan et al., (2012) indicated that the combination of hand weeding and maize-soybean intercropping were more effective in terms of weed suppression and enhanced yield of maize. Having a good understanding of the effects of intercropping and hand weeding on weeds will be a significant contribution to efficient weeds control and appropriate design of crop systems.

The aim of the study was to estimate the combined effects of maize-soybean intercropping and hand-weeding on weed suppression without herbicide usage. The study was expected to answer the following questions: how do the different spatial arrangements and hand-weeding frequency control weed in maize-soybean intercropping? Is the hand weeding necessary to control weed efficiently in maize-soybean intercropping?

2. MATERIAL AND METHODS

2.1. Research site and soil characteristics

The study was conducted on research farm at Viet Nam National University of Agriculture (VNUA), Ha Noi, Viet Nam in both spring-summer and winter seasons in 2013. Soil samples were taken at the beginning of the spring-summer season and chemical analysis was conducted to determine main nutrient availability. The soil used in the study is alluvial with OC= 0.76%, total nitrogen N = 0.08%, P_2O_5= 0.17%, K_2O = 1.72%; N_{TP}= 30 mg kg^{-1}, P_2O_5= 69.5 mg kg^{-1}, K_2O= 8.0 mg kg^{-1}.

2.2. Experimental design

The experiments were arranged in a split-plot design with three replications. The treatments were a combination of intercropping arrangement (main factor - Fig. 1) and weeding frequency (sub-factor). In spring-summer season, there were three planting patterns: M0 (sole maize), M1 (maize + 1 row of soybean in the interrow of maize) and M2 (maize + soybean in the same row with maize). In winter season, M2 method was replaced by M3 method (maize + 2 rows of soybean in the inter-row of maize) due to the result of the winter-spring season and lower light intensity. The weeding regimes applied in both seasons were: NW (No-weeding), HW1 (1 hand weeding at 3-4 leaf stage of maize), HW2 (2 hand weeding at 3-4 and 8-9 leaf stages of maize). Hand weeding was done by the use of a hand hoe.

Maize seeds cv. NK4300 were sown at a density of 64,000 plants ha^{-1} at 60cm row spacing, on February 28 in spring-summer season and on September 20 in winter season. In all intercropping treatments, soybean seeds cv. DT96 were sown on the same day with maize and the plant population of soybean was maintained at 128,000 plants ha^{-1}. Subplot size was 2.5 x 5m with four maize rows.

In both seasons, experimental plots were supplied with 120 kg N, 90 kg P_2O_5 and 90 kg K_2O ha^{-1}. The total amount of P_2O_5 was supplied on the day of sowing. The amount of nitrogen and potassium were split equally into three applications after each weed collection.

2.3. Data collection

Weed and volunteer density were determined within three quadrats ($0.25m^2$) randomly placed in each sub-plot at three growth stages: 3-4 leaf stage (S1), 8-9 leaf stage (S2) and 13-14 leaf stage (S3) of maize. The weeds within each quadrat were oven-dried at 80^0C for 48 hours and weighed to determine dry biomass. In hand weeding treatments, weed collection was carried out before weeding.

Rainfall and air temperature were collected from Lang Ha weather station located in Ha Noi. In 2013, rainfall was below 50mm per month from January to April before reaching the peak in August. From May to September, the rainfall was always over 200 mm per month and then decreased to nearly zero in December (Fig.2). The average temperature was about 24°C in March and increased steadily during the spring-summer season. In contrast, in the winter maize season, the temperature was above 25 °C at the beginning of the season and slightly reduced from November.

2.4. Statistical analyses

Data were statistically analysed using with CROPSTAT 7.2. The significant difference between means was separated by the least significant difference (LSD) at the 5% probability level.

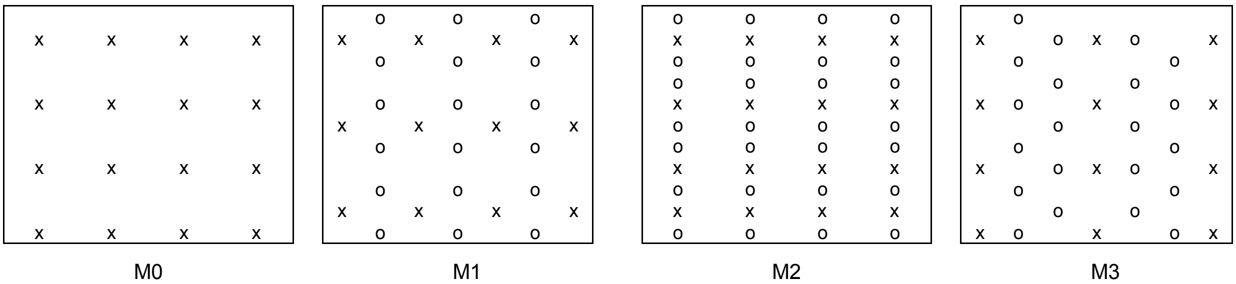


Figure 1. Different methods of maize (X) and soybean (O) intercropping in the experiments

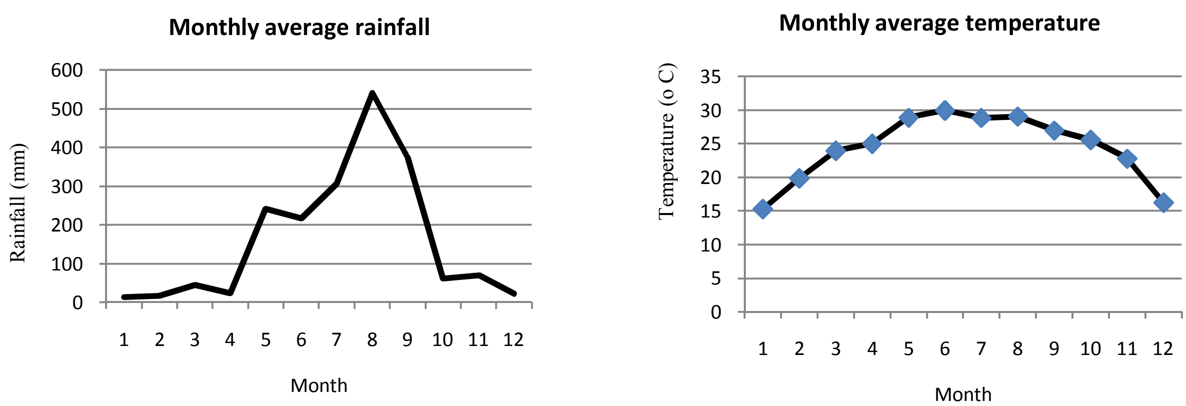


Figure 2. Monthly average rainfall and temperature in 2013

Note: Data collected from the weather station in Lang Ha, Ha Noi

3. RESULTS AND DISCUSSION

3.1. Effect of hand weeding on weed density

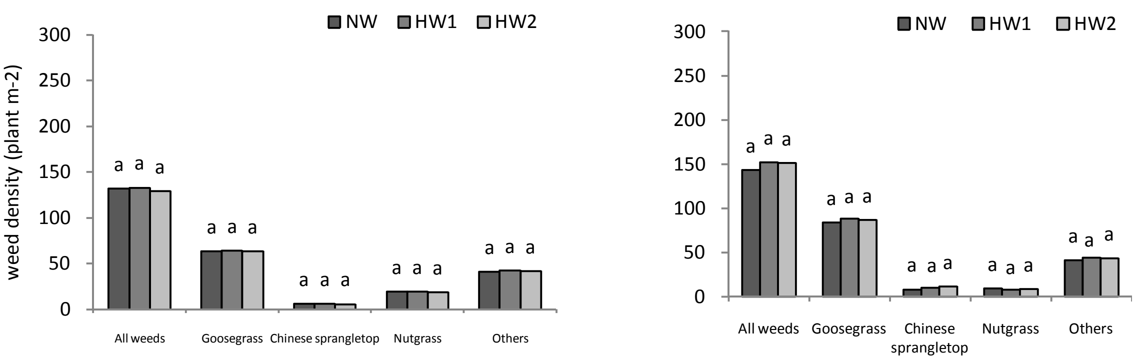
Total weed density in no weeding and hand weeding plots was not different at S1 stage of maize (Fig. 3). However, at S2 and S3 stages, total weed density was significantly lower in hand-weeding treatments compared with no weeding control. Ali et al., (2011) and Khan et al., (2012) also indicated that hand weeding was the most effective way to control weed density in maize field. Although hand weeding strongly reduced densities of Goosegrass and Chinese sprangletop at the S2 and S3 stages of maize in both seasons, but showed no effect on the density of Nutgrass in the winter season.

In both seasons, the lowest weed density was recorded in plots where double hand-weeding was practiced. Although total weed density in one hand weeding plots was lower than that in no-weeding plots, it was still high at the third sampling, particularly in the latter season. Our results suggested that the double hand-weeding was effective for controlling Goosegrass and Chinese sprangletop.

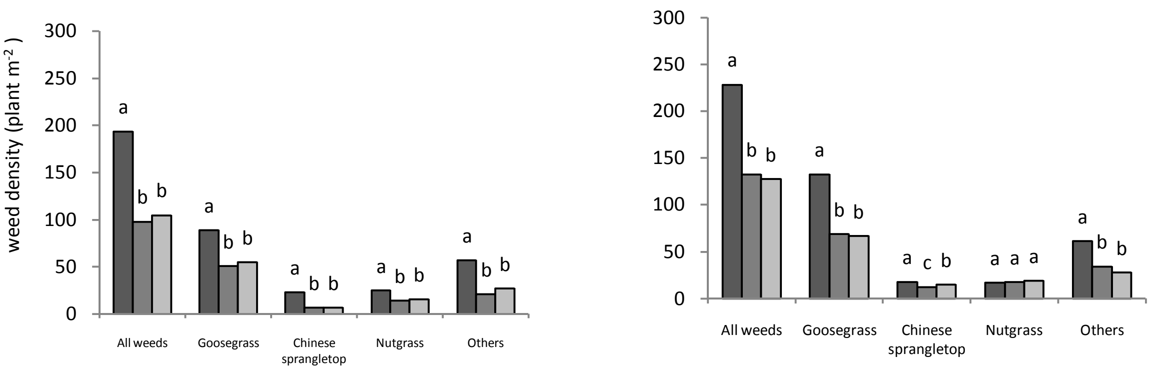
3.2. Effect of maize-soybean intercropping on weed density

In spring-summer season, there was no difference in weed density between sole cropping and intercropping plots at S1stage (Fig. 4). At S2 and S3 stages, total weed density and the densities of Goosegrass, Chinese sprangletop and Nutgrass in intercropping treatments were significantly lower than those in sole maize planting. Intercropping significantly reduced the density of Nutgrass at

3-4 leaf stage of maize (S1)



7-8 leaf stage of maize (S2)



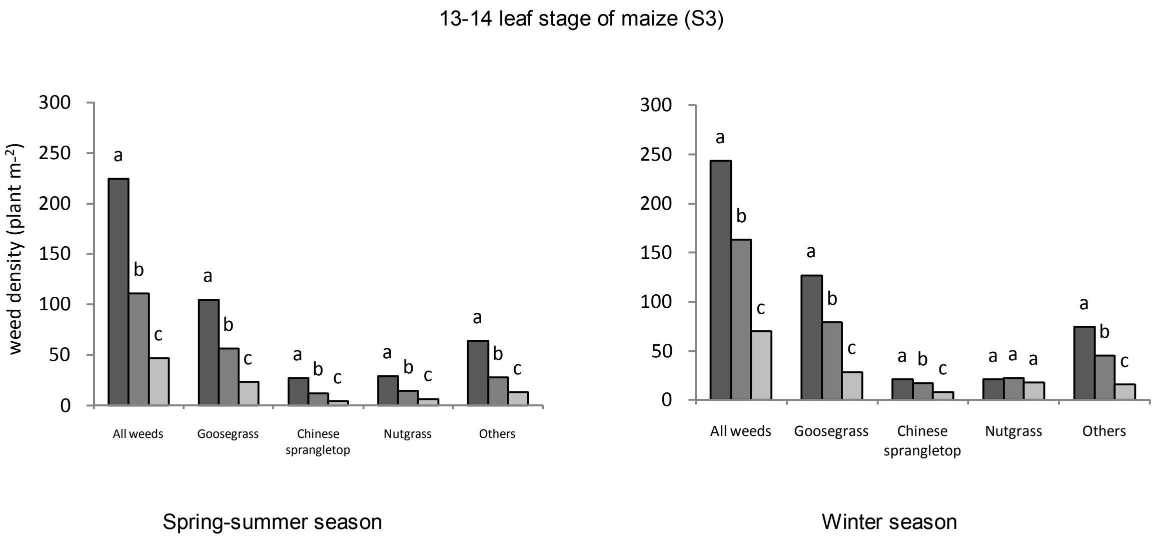
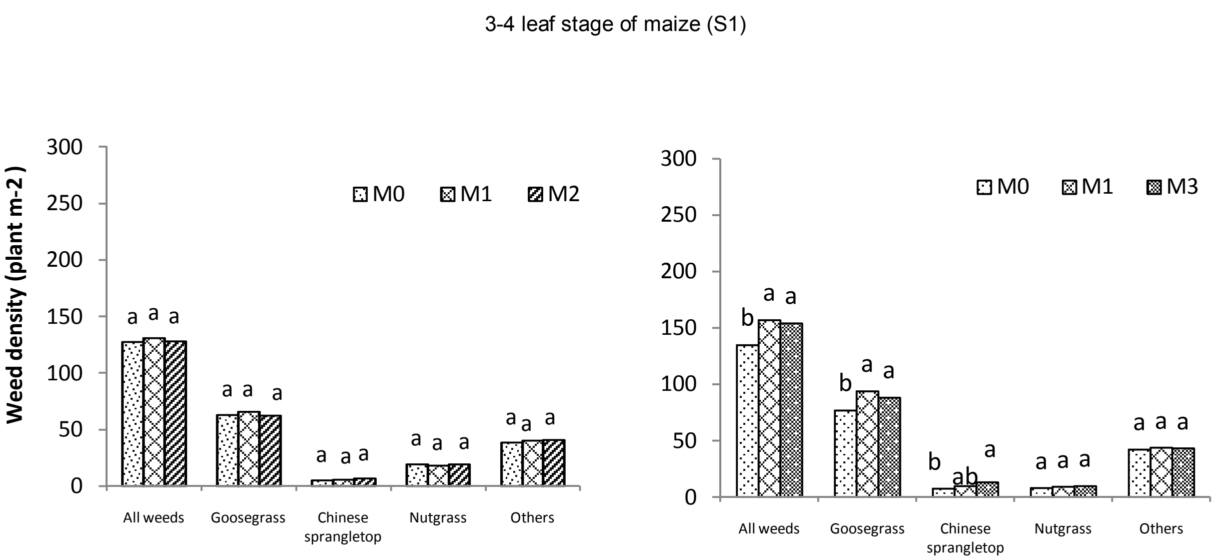


Figure 3. Weed density of Goosegrass (*Eleusineindica)*, Chinese sprangletop (*Leptochloachinensis*), Nutgrass (*Cyperusrotundus)* and other weeds at three growing stages of maize as influenced by hand weeding

Note: NW: no-weeding, HW1: one hand-weeding, HW2: 2 hand-weeding.
The similar letters above bars indicate no significant difference in weed density at α= 0.05 according to the LSD test.

S3 stage while the density of Chinese sprangletop was not affected. The reduction in total weed density under M1 intercropping pattern was greater than under M2 , which might be attributed to the result of the reduced Goosegrass density.

In contrast, total weed density was higher in intercropping plots than in sole maize at S1 stage in winter season (Fig. 4). It is likely that the addition of one or two rows of soybean in the inter-rows of maize stimulated seed germination of Goosegrass and Chinese sprangletop as a result of seedbed preparation for soybean, warm temperature and high precipitation at the beginning of the second season. (Fig. 2).



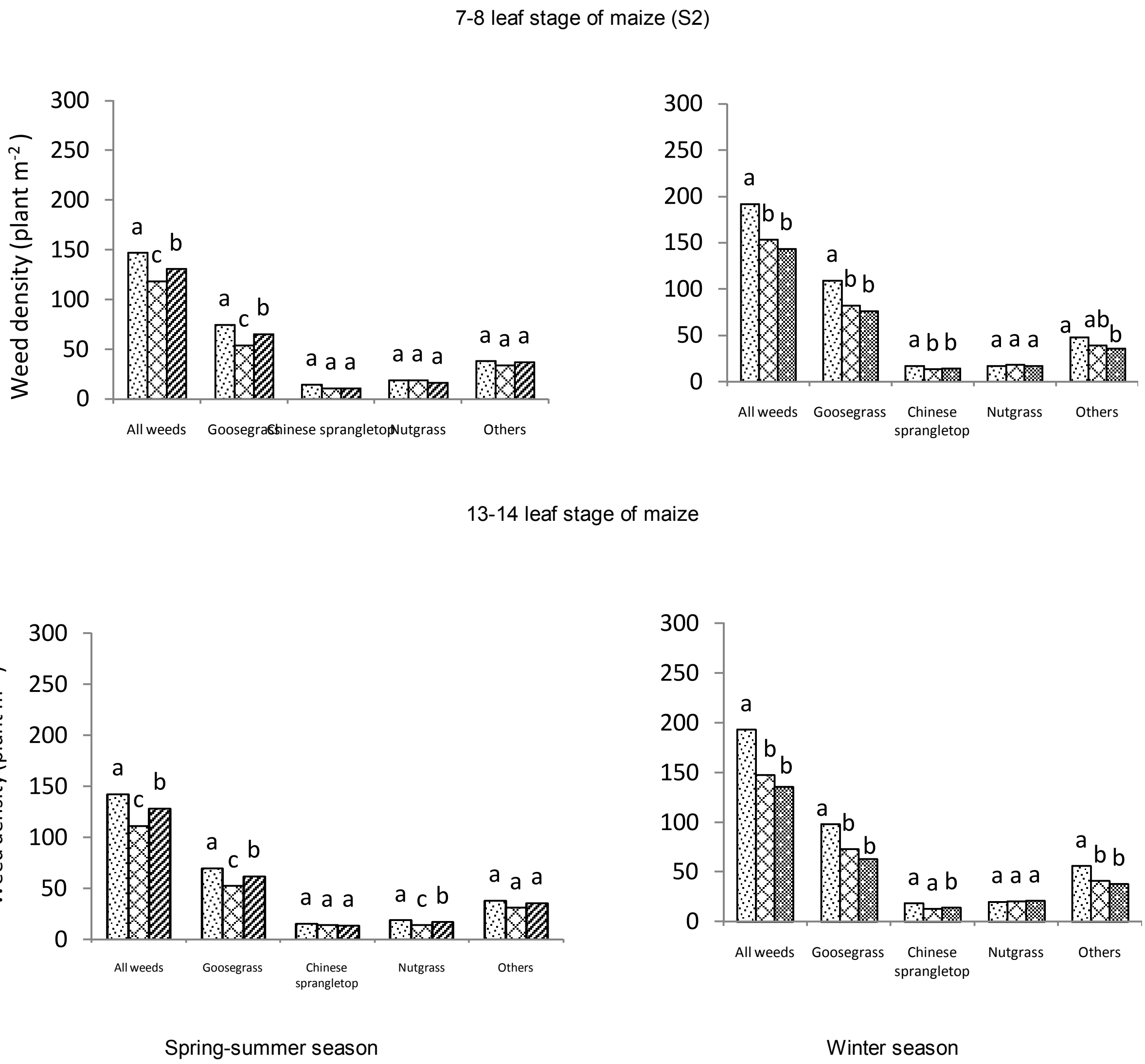


Figure 4. Weed density of Goosegrass (*Eleusineindica)*, Chinese sprangletop (*Leptochloachinensis*), Nutgrass (*Cyperusrotundus)* and other weeds at three growing stages of maize as influenced by different intercropping methods

Note: Mo: maize sole, M1: planting one soybean row in the inter-row of maize, M2: planting soybean in the same row with maize, M3: planting two rows of soybean in the inter-row of maize. The similar letters above bars indicate no significant difference in weed density at α= 0.05 according to the LSD test.

However, at S2 and S3 stages of maize, all intercropping treatment reduced total weed density significantly compared to sole maize. The difference was largely contributed by the decrease in densities of Goosegrass and Chinese sprangletop. These results also showed that Goosegrass had the greatest density in both seasons. Although the density of Goosegrass in intercropping treatments was lower compared to sole maize, its density was still more than 50 plants m^{-2} in all treatments at the 13-14 leaf stage of maize (Fig. 4). However, the density of Goosegrass was strongly reduced by hand weeding.Lowest density of this grass was observed in 2 hand-weeding treatments (Fig. 3). These results suggested that the combination of intercropping and hand-weeding may effectively control Goosegrass.

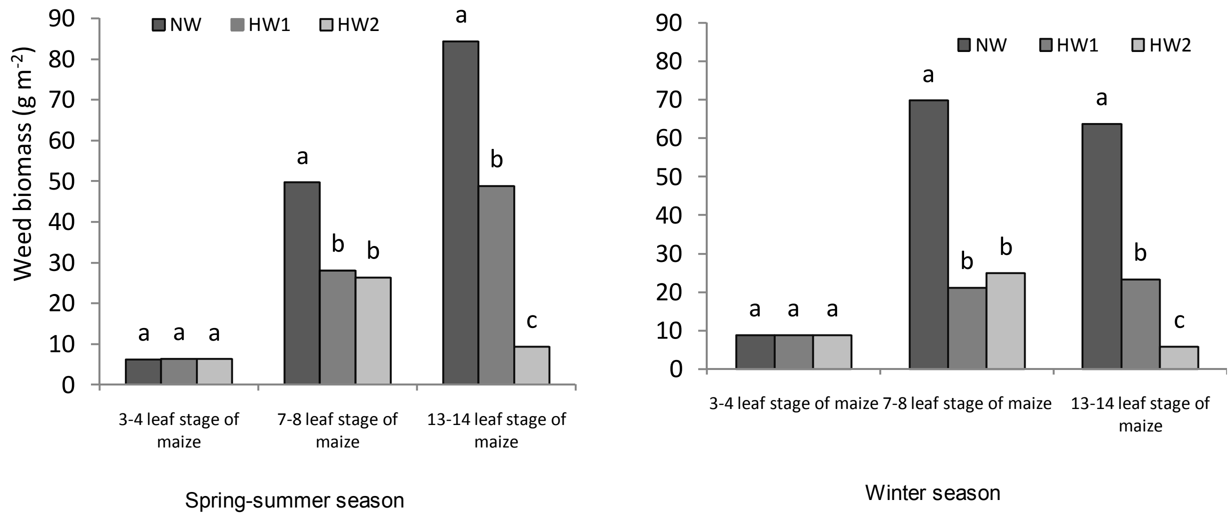


Figure 5. Effect of hand weeding

Note: NW: No-weeding, HW1: one hand-weeding, HW2: 2 hand-weeding) on total weed biomass at three growing stages of maize. The similar letters above bars indicate no significant difference in weed biomass at α= 0.05 according to the LSD test.

3.3. Effect of hand weeding on weed biomass

Statistical analysis showed a significant effect of hand weeding on weed biomass (Fig. 5). One and 2 hand weeding reduced remarkably total weed biomass at S2 and S3 stages in comparison with unweeded control. The highest weed biomass was found in unweeded plots where total weed biomass increased strongly from S1 stage to S3 stage. While total weed biomass slightly increased from S2 to S3 stage in one hand weeding treatment, a dramatic reduction to below 10 g m^{-2} at S3 stage was recorded at 2 hand weeding treatments in both seasons.

3.4. Effect of maize-soybean intercropping method on weed biomass

There was a significant difference in total weed biomass between intercropping treatments and sole maize (Fig. 6). In spring-summer season, the M1 intercropping pattern resulted in a greater total weed biomass compared to sole maize (M0) and the M2 intercropping method at S1 stage. However, at S2 and S3 stages, both intercropping patterns significantly reduced y weed biomass comparing to sole maize. At S3 stage, total weed biomass was lowest in the M1 intercropping method, which implies that the M1 intercropping method suppressed weed growth better than the M2 method.

In winter season, the intercropping treatments had higher total weed biomass at S1 stage when compared to sole maize planting. At S2 and S3 stages, both intercropping methods led to significant reduction in total weed biomass; however, the highest reduction rate was observed in the M3 method.

Our results indicated that intercropping reduced density and biomass of weed significantly. The similar results were reported in previous studies that intercropping effectively reduced weed density and biomass compared with sole crop (Bantilan et al., 1974; Furoc et al., 1977; Moody, 1977; Shetty and Rao, 1981; Responso et al., 1982; Shah et al., 2011; Sharma and Banik, 2013). The reduction of weed growth can be the result of competition between crops and weed fornutrients, sunlight, moisture and the space in intercropping compared to sole cropping (Moody, 1980; Eskandari Hamdollah, 2011; Mohler and Liebman, 1987; Poggio, 2005; Sharma and Banik

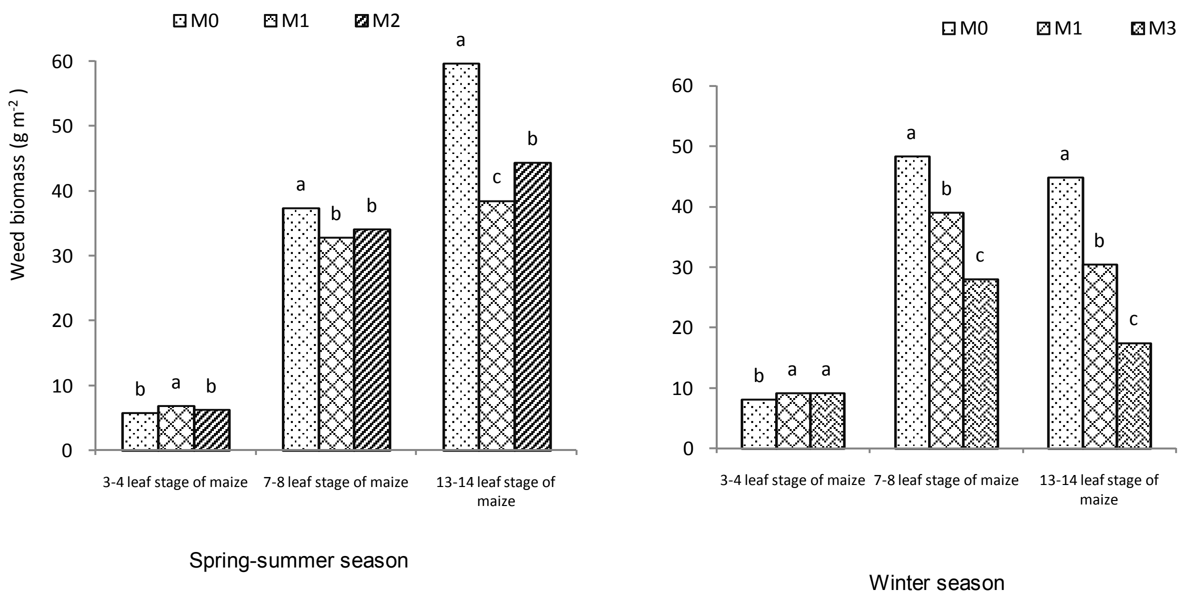


Figure 6. Effect different intercropping methods on weed biomass

Note: Mo: maize sole, M1: planting one soybean row in the inter-row of maize, M2: planting soybean in the same row with maize, M3: planting two rows of soybean in the inter-row of maize. The similar letters above bars indicate no significant difference in weed biomass at α= 0.05 according to the LSD test.

Banik, 2013). Besides, the modification of light quality and soil temperature in the intercropping also resulted in the decline of weed emergence and low species diversity (Sharma and Banik, 2013).

3.5. Interactive effect of hand weeding and intercropping on weed biomass

The total dry matter of weed was significantly reduced by the combination of hand weeding and intercropping (Table 1). Although intercropping plots without weeding led to a strong reduction in weed biomass, the reduction rate was significantly lower than under intercropping and hand-weeding interaction. In both seasons, the lowest weed biomass was found in maize-soybean intercropping combined with 2 hand-weeding. The results suggested that additional weeding is necessary to suppress weed growth in intercropping system, which was also reported in other studies (Shetty et al., 1979 and Moody, 1977; Carruthers et al., 1998).

Maize and soybean plots grown in the winter season showed higher weed density (Figs. 3 and 4) but lower weed biomass than those in the spring-summer season, except for S1 stage (Table 1). The noticeable difference between two seasons might be attributed to the difference in the weather condition. The lower temperature and precipitation at the beginning of the spring-summer season could be the limiting factors for weed germination and growth. However, the increase in temperature, light intensity and rainfall from April to the end of the season stimulated weed growth. In contrast, the rainfall declined strongly from more than 350 mm in September to below 100 mm in October in winter season (Fig. 2).

Table 1. The dry matter of weed (g m^{-2}) as the interactive effect of hand weeding and intercropping in spring-summer and winter seasons

Weeding	spring-summer season				Winter season			
	M	3-4 leaf	7-8 leaf	13-14 leaf	M	3-4 leaf	7-8 leaf	13-14 leaf
NW	M0	5,8^{c}	54,1^{a}	100,2^{a}	M0	7,9^{bc}	84,7^{a}	90,1^{a}
	M1	6,9^{ab}	45,9^{b}	72,9^{c}	M1	8,9^{ab}	69,8^{b}	63,7^{b}
	M2	6,4^{abc}	49,4^{b}	80,0^{b}	M3	9,9^{a}	54,9^{c}	37,3^{c}
HW1	M0	5,8^{c}	31,8^{c}	65,9^{d}	M0	7,6^{c}	26,1^{de}	35,0^{c}
	M1	7,0^{a}	25,7^{d}	35,8^{f}	M1	9,8^{ab}	23,0^{ef}	22,5^{d}
	M2	6,3^{abc}	26,7^{d}	44,7^{e}	M3	8,9^{a}	14,2^{fg}	12,3^{e}
HW2	M0	5,9^{c}	26,2^{d}	12,9^{g}	M0	8,7^{ab}	34,4^{d}	9,6^{ef}
	M1	6,8^{ab}	26,8^{d}	6,8^{h}	M1	9,0^{a}	25,3^{e}	5,2^{ef}
	M2	6,2^{ac}	26,2^{d}	8,4^{gh}	M3	8,8^{ab}	14,9^{fg}	2,7^{f}
$LSD_{0,05}$		*0,81*	*3,60*	*5,23*		*0,91*	*8,42*	*7,74*
CV%		*6,7*	*5,8*	*6,1*		*5,8*	*12,3*	*14,1*

Note: M: intercropping method; Mo: maize sole, M1: planting one row of soybean in the inter-row of maize, M2: planting soybean in the same row with maize, M3: planting two rows of soybean in the inter-row of maize. NW: No-weeding, HW1: one hand-weeding, HW2: 2 hand-weeding. The similar letters above bars indicate no significant difference in weed density at α= 0.05 according to the LSD test

4. CONCLUSION

Even there was a seasonal effect on weed control, weed density and biomass were significantly reduced by maize-soybean intercropping and hand-weeding in both seasons. The lowest density and biomass of weed was observed in the combination of maize-soybean intercropping with 2 hand-weeding. Although intercrop reduced weed biomass and density significantly, our results suggested that maize-soybean intercropping should have a 2 hand-weeding in addition.

In the study, Goosegrass (*Eleusineindica)* was the dominant weed species. However, it was strongly suppressed by maize-soybean intercropping and hand weeding. The density of Nutgrass (*Cyperusrotundus)* was negligiblly affected by intercropping as well as hand-weeding. Further research should aim to estimate the effect of hand weeding and maize/soybean intercropping on the accumulation of weed seed in the soil.

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