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Study of relationship between soybean (*Glycine max* (L.) Merr.)planting spatial arrangements and velvetleaf (*Abutilon theophrasti* L.) population dynamic

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ABSTRACT

The velvetleaf is an important annual weed in the Mazandaran province, Iran. Seeds are the only way of propagation and renewal of this weed. More knowledge was gained regarding soil seed bank and its seed production to improve the management of the velvetleaf weed in the future. There is a minimal information concerning the impact of the soybean planting pattern on the dynamics of the velvetleaf population. For this reason two different fields have been studied with the cooperation of the Agriculture Discipline of the Islamic Azad University, in Qaemshahr, Iran, during 2009 and 2012. In this study the effect of two types of soybean row spacing were used, 50 cm-wide and 36 cm - narrow, and three emergences of the velvetleaf weed population (periods 0-10, 10-20 and 20-30 days after soybean sowing were implemented) were studied. Seed production, leaf area and dry matter increased in each plant population of the velvetleaf weed in the 50-cm soybean rows. Mortality rates were decreased in velvetleaf's seedling population in the wider spaced rows. By observation it was seen an increased production of seeds in the first batch of seedlings. It appears that we must remove the first weed emergence flushes within three to four weeks after the soybean emergence to prevent reduced yields in the soybean crop and further increase of the velvetleaf seed bank.

Key words: row spacing, cohort, velvetleaf, soybean

IZVLEČEK

PREUČEVANJE RAZMERJA MED PROSTORSKO UREDITVIJO SETVE SOJE (*Glycine max* (L.) Merr.) IN POPULACIJSKO DINAMIKO BRŽUNASTEGA OSLEZOVCA (*Abutilon theophrasti* L.)

Bržunasti oslezovec je pomemben enoletni plevel v provinci Mazandaran, Iran. Njegovo razmnoževanje je izključno s semeni. V raziskavi so bila pridobljena nova spoznanja o semenski banki in produkciji semena za izboljšanje uravnavanja bržunastega oslezovca v bodoče. Malo je informacij, ki se nanašajo na vpliv načina setve soje na dinamiko polpulacij bržunastega oslezovca. V ta namen sta bili v sodelovanju z Agriculture Discipline of the Islamic Azad University, Qaemshahr, Iran, v letih 2009 in 2012 preučevani dve polji, na katerih sta bila preučevana načina setve soje v vrstah s širšim razmikom, 50 cm, in v vrstah z ožjim razmikom, 36 cm, na vznik populacij bržunastega oslezovca v treh različnih obdobjih po setvi soje (0-10, 10-20 in 20-30 dni). Produkcija semena, listna površina in vsebnost suhe snovi so se povečali v vsaki naslednji populaciji bržunastega oslezovca pri setvi soje v vrstah s širšim, 50 cm razmikom. Mortaliteta kalic bržunastega oslezovca se je pri tem načinu setve soje iz populacije v populacijo zmajševala. Pri tem smo opazili povečano produkcijo semena rastlin bržunstega oslezovca, ki so vzkalile v prvem obdobju po setvi soje. Iz tega lahko zaključimo, da je potrebno zatiranje plevelov v prvem obdobju po setvi soje, to je v treh do štirih tednih po vzniku soje, če hočemo preprečiti zmanjšanje pridelka soje in nadaljne povečevanje semena bržunastega oslezovca v semenski banki. Neupoštevanje širine razmika med vrstami pri setvi soje kaže na pomen tega dejavnika pri uravnavanju populacij te plevelne vrste.

Ključne besede: razporeditev vrst setve, kohorte, bržunasti oslezovec, soja

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1 INTRODUCTION

Several new methods and technologies were used to reduce the population of the weed to adequate levels. However for preserving the existing environment and other natural resources it is essential the use of various methods and techniques such as integrated weed management control (IWM). The purpose of this method in this part is to reduce our reliance on chemical weed control which can be accomplish through development and utilization of integrated weed management (IWM) as well as integrating other preventive measures (Knezevic and Horak, 1998). Integrated weed management (IWM) emphasizes the health of the product, and a crucial understanding of this method and its accurate application (Swanton et al., 2008). This approach has demonstrated the relevance and importance of weed mortality and decline of the weeds fitness (Williams et al., 1998). It is a combination of various methods by cultural, chemical and mechanical means (Swanton et al., 2008) as well as agronomical operations which also play a vital role (Pylon et al., 1997; Hock et al., 2005). Articles on the timing and placement of fertilizer, seeding rate and reducing crop row spacing have been studied and reported by Walker and Buchanan, (1982). Planting the soybean with a smaller distance between the plant rows leads to acceleration in canopy closure thus increasing its relative competitiveness and weed suppression particularly in the final weed cohorts (Knezevic et al., 2003b; Mickelson and Renner, 1997; Mulugeta and Boerboom, 2000; Nice et al., 2001; Yelverton and Coble, 1991; Yong et al., 2001). Knezevic et al (2003 a, b) demonstrated in his study that with decrease in row spacing of the soybean the toleration of the crop was increased to constrain the weed competition at the onset of the season. The critical weed free period was delayed and in general severity of weed damage declined. Other studies have shown that by increasing the plant dry mass, the seed production per bush were increased (Martens and Jansen, 2002; Thompson et al., 1991; Samson and Werk, 1986). Therefore, it can be purposed that the crop planting pattern affects the production ability of velvetleaf seed. It is insufficient research regarding the influence of the planting pattern on the velvetleaf seed production.

Effective, logical and long term weed management is based on the constant reduction of weeds' population and seed bank density. One of the most important factors in this area is to minimize seed production per plant. This result has been done by reduction of weed density or by mean of diminishing the seed production.

Process of emergence is a critical event in the life cycle of the velvetleaf weed (Forcella et al., 2000). Period of weed emergence and dynamics of weed emergence flushes play a critical role on loss of the crop yield (O'Donovan et al., 1985; Swanton et al., 2008). The growth of the velvetleaf seedlings which emerge at the beginning of the season is often compared with the later ones. The seedlings developed in the early part of the season demonstrate more competitiveness, produce a higher biomass and number of seeds, and furthermore have added impact on the crops' yield ability (Massinga et al., 2001; Norsworthy et al., 2007; Steckel and Sprague, 2004).

The low competitiveness of the seedlings which emerge later in the season is mainly due to the interspecies competition and their mortality rate under the canopy. This was noted to occur most likely in the dense row spacing and it was as a consequence of shading by crop (Buehring et al., 2002; Norsworthy et al., 2007).

For the future success and development of integrated weed management (IWM), further biological studies of the various weeds inhibiting the soybean culture is necessary. Velvetleaf is a serious and troublesome weed of the soybean in the north of Iran and a global dilemma (Shafigh et al., 2006; Rezvani et al., 2008; Sadeghi et al., 2003; Warwick and Blank, 1988; Hock et al., 2005; Zeinali and Ehteshami 2003). The majority of the velvetleaf seedlings sprouted at the beginning of the season and some emerged mid-season (Egley and Williams, 1991). Velvetleaf seedlings are able to complete their life cycle in the crop canopy (Mitch, 1991) and can produce as much as 17000 seeds per plant (Warwick and Black, 1988).

The goal of this study is to see the interactions between the various velvetleaf cohorts during (0-

10, 10-20, and 20-30 days after crop planting) in the disparate soybean planting patterns (36 and 50-cm row spacing).

2 MATERIAL AND METHODS

This experiment has been done in the scientific-research fields of the Islamic Azad University in Qaemshahr, Iran; formatted and randomized in complete block design, in three replications in the two season crops of 2009 and 2012. Treatments for this study were different planting patterns in the soybean culture. Soybean seeds were planted in two different row spacing in order to achieve a 45 plants per m^{-2} on 15 April 2009 and 18 April 2012. At the first plant-group, the distance between rows was 36 cm (narrow spaces) and the seedlings intervals were 6 cm in the rows and in the second plant-group the distances between rows were 50 cm (wide spaces) and 4 cm intervals between the seedlings in the row, respectively.

The soybean seeds ('JK' variety) were disinfected with Benomyl fungicide (2000 ppm), and then planted at a depth of 2 cm. A segment of the university's research-field was selected which was known to be positive for contamination of the velvetleaf seed. Experimental units were 7 m long and 3.2 m up to 4.5 m wide with 10 rows.

The field was tillaged twice (the autumn in previous year and prior to planting after the next year). According to the soil tests there were no need to apply potassium (K_2O), however, phosphorus (P_2O_5) and nitrogen (urea) fertilizers were used at 80 kg h^{-1} and 5 kg h^{-1}, respectively.

By Auger, five soil samples were taken from each plot, prior to sowing the soybean seeds, the diameter and depth of each sample was 6 cm and 10 cm, respectively. The purpose of these samples were to confirm the presence and removal of the velvetleaf seeds (*Abutilon theophrasti* Medik), all samples were taken to the university laboratory. Soil samples were put into plastic bowls which contained potassium hexametaphosphate (5 %), then were mixed with distilled water disintegrating soil structures, then the solution of soil solid particles was filtered through a sieves of 1 mm diameter, at last following confirmation and identification of the velvetleaf seeds, the seeds were collected. Subsequent to counting the seeds in the augered sectioned areas, the seeds' density per unit soil surface was estimated.

For recording and sampling during the growth season two quadrats, 1m × 1m, were selected in the center of each plot. For determination of the effects of the velvetleaf seedlings emergence stages their appearance were divided into three cohorts: zero to 10, 10 to 20 and 20 up 30 days after soybean sowing. Calculations for the number of seed per unit soil volume and surface, rate of recruitment was measured. The seedling mortality was also calculated in the form of percentage. The other undesirable weeds were controlled by hand-hoeing.

Developmental stages were based on the number of fully expanded leaves per plant (Fehr and Cavines, 1977). Velvetleaf bushes were clipped at the soil surface, divided into 40 - cm segments, then leaves, stems and capsules were separated from each other at physiological maturity of the soybean. The leaf area (LA) of the velvetleaf was measured with a leaf area meter (LTD AM 200). Different plant components were then dried at 80 C° in the oven (Memmert DIM 40050) and weighed. Seeds that had scattered on the ground before or at the final harvest were not collected, and seeds losses were not estimated. Analysis of variance was performed using PROC MIXED (SAS, 1999) to test data normality and significance ($P < 0.05$) of growing scenario, soybean row spacing and velvetleaf relative emergence.

3 RESULTS AND DISCUSSION

The average number of velvetleaf seed in the soil was 943 and 991 seeds m^{-2} at the 2009 and 2012, respectively. This amount was in agreement with other studies (Lindquist et al., 1995; Munger et al., 1987). This result could have risen from the intense contamination of soil with this weed or was caused by a lack of continual crop planting.

Initially, the rate of the velvetleaf seedlings emergence cannot be influenced by a soybean planting pattern. Differences in the velvetleaf seedlings emergence in two different rows spacing's can be related to their content on the weed seed bank (Table 1). The mean of the velvetleaf seed density during two years of study in the soil seed bank in wide and narrows rows were 1215 and 720 seed per m^{-2}.Therefore higher number of velvetleaf seedlings in wider rows soybean planting appears to be a logical outcome. The lack of necessity to light for velvetleaf seed germination may explain this result (Bello et al., 1995).

Table 1: Velvetleaf seed rate in seed bank, emergence seedlings density and recruitment percentage in various soybean row spacing for 2009 and 2012[1]

Year	Seed bank (sb) (seed/m^2) Row spacing (cm)		Seedling density (sd) (p/m^2) Row spacing (cm)		Recruitment sd/sb×100 Row spacing (cm)	
	36	50	36	50	36	50
2009	708	1179	10	22	1.4	1.8
2012	732	1251	12	25	1.6	2.0

1- Within a row the same letter indicates that the values did not differ significantly by LSD test, according to P=0.05

Velvetleaf population recruitment was insignificant regarding planting pattern (averaging 26 %, Table 1). In comparison with other experiments our study gave results with smaller values of this parameter (Puricelli et al., 2002). Lindquist et al (1995) also found this consistency in his study. This information can be used to predict the approximate amount of emergence percentage from the weed seed bank. Of course, in the majority of weed species more differences are recorded between the content in weed seed bank and emerging seedlings (Forcella et al., 1997). These variations maybe caused by the sizes of the sampling areas or the time of samplings (Derksen and Watson, 1998).

The rate of the velvetleaf seedlings mortality was lower in the wide-rows (Table 2). Despite slower growth of velvetleaf seedlings in the narrow rows, they were able to survive relative to their condition (higher in the second cohort). Puricelli et al (2002), in his study regarding the interference between *Anoda cristatae* L. and the soybean, reported similar results. However, Scursoni et al (1999) observed mortality of *Avena fatua* L. plants in the densest stands of barley, due to the acceleration in the canopy closure. Nonetheless, in this study, further delay in the emergence of the velvetleaf population relative to the soybean caused the decrease in their survival. High survival of early cohorts of velvetleaf seedlings in both row spacing of soybean indicated important role on information of their soil seeds bank.

Observation of the velvetleaf seedling population in the last cohorts, during the soybean harvest it has shown that they did not survive. Therefore it was noted that the control measures must be predominantly focused on the removal of the early cohorts. Therefore the results were demonstrated that the loss of the soybean yield was a result of the competition with the first cohorts of velvetleaf seedlings (Cowan et al., 1998; Dielman et al., 1996; Steckel and Sprague, 2004). Researches have showed that velvetleaf plants which emerged 35 days after soybean planting did not decrease crop yield significantly (Zimdahl, 1988). This indicates the importance of time of velvetleaf seedlings emergence for their survival (Hock et al, 2005), the same was proved also for *Digitaria sanguinalis* (L.). (Gallart et al, 2010; Oreja and dela Funte. 2005) and some other weed species (Lindquist et al., 1995).

Table 2: Emerged seedlings number, mortality and survival percentage of velvetleaf in cohorts and planting patterns for 2009 and 2012

Year	Cohorts[1]	Emerged seedling number (p/m^2)		Mortality (%)		Survival (%)	
		row	spacing	row	spacing	row	spacing
		36 cm	50 cm	36 cm	50 cm	36 cm	50 cm
2009	1	5 b**1**	14 c	43 c	40 c	57 c	60 c
	2	3 a	5 b	60 b	66 b	40 b	34 b
	3	2 a	3 a	100 a	100 a	0 a	0 a
2012	1	7 c	18 c	40 c	37 c	60 c	63 c
	2	4 b	9 b	51 b	60 b	49 b	40 b
	3	2 a	4 a	98 a	100 a	2 a	0 a

1-It means emergence date of velvetleaf at 10 th intervals after soybean planting (for details refer to the text in table 3)
2-Within a top column, the same letter indicates that the values did not differ significantly by LSD test, according to *P*=0.05

Dry matter accumulation in the velvetleaf population was affected by the planting pattern (Table 3). The velvetleaf populations benefited more in their biomass in the wide soybean row spacing. Seedlings that emerged in the first cohort in 50-cm row generated almost four times higher plants with respect to the second cohort. Similarly the velvetleaf populations in the narrow soybean row spacing as with the first cohort in comparison with the second cohort had 200 % more dry matter. Overall the seedlings that were emerged earlier produced additional biomass. These outcomes were confirmed by the findings of Massinga et al. 2001, Puricelli et al. 2002 and Hock et al., 2005.

Leaf areas of velvetleaf plants accumulated in the third and fourth layer 77 % and 71 % for the 50-cm-row and 36-cm-row soybean respectively, an average in both years. The highest leaf accumulation area in the upper strata's of the velvetleaf canopies indicates higher efficiency in competition for intercepting the light in comparison with the soybean. Other experiments have reported similar reactions during mixed culture between soybean with velvetleaf (Heindl and Burn, 1983; Hock et al., 2005) and the redroot pigweed (Legere and Schreiber, 1989). Hock et al (2005) reported that velvetleaf population had low leaf area in the lower layers when it was located with soybean in mixed cultures.

Table 3: Velvetleaf seed production and plant dry mass in cohorts at different planting patterns different for 2009 and 2012 season

Year	Row spacing	Emergence date of velvetleaf		Leaf stage of soybean	Seed number per plant	Plant dry mass (g)
2009	36	May 15	May 25	V_E	1098 (143)	18.4
		May 26	Jun 4	V_1	509 (143)	9.6
		Jun 5	Jun 14	V_2	0	0
	50	May 15	May 25	V_E	2372 (143)	39.96
		May 26	Jun 4	V_1	683 (143)	10.0
		Jun 5	Jun 14	V_2	0	0
2012	36	May 19	May 29	V_E	716 (26)	17.9
		May 30	Jun 9	V_1	264 (29)	6.6
		Jun 10	Jun 19	V_2	0	0
	50	May 19	May 29	V_E	1881 (169)	37.6
		May 30	Jun 9	V_1	527 (47)	7.9
		Jun 10	Jun 19	V_2	90 (8)	0

1- Standard error based on least square means (*P*=0.05)

The velvetleaf leaf area was influenced by the soybean-planting pattern and its' relative time of emergence ($P < 0.05$) (Figure 1). Leaf area of velvetleaf plants within the soybean showed more reduction in 36-cm-row planting at the second cohort. In the narrow-row spacing on average in both years the leaf area of velvetleaf population in the first and second cohort were reduced up to 24 % and 30 %, respectively. With a further-decline of the leaf area in 36-cm-row; expressing further competition for the light, more so in the second cohort.

The time of emergence plays an important part in the velvetleaf seedlings survival, in so far as those emerging early produced a higher seed population and increased further soil seed banks, as illustrated in Table 3. The variations are demonstrated and can be justified by the unsymmetrical competition for plants in different cohorts (Schwinning and Weiner, 1998). Thus, the bushes which were emerged early had a longer growing period and also were larger. Hock et al (2005) and Gallart et al (2010) demonstrated the importance of time emergence for seed production in velvetleaf and orchard grass weed populations. Thus the dynamics of the seed bank can be influenced by each cohort and were resulted in producing seeds with different dormancy's and reactions of their environmental conditions (Baskin and Baskin, 2001).

Seed production in the velvetleaf populations were reduced in the narrow-row spacing and due to their delayed time of emergences (Table 3). Seedlings that emerged in the first cohort in wide rows generated twice the amount of seeds on each of the plants.

These differences were smaller in the later cohorts. Furthermore, the seed production in different flushes in the wide rows had a higher variance. The competition for light accounts for the decline in seed productions (Puricelli et al., 2002; Buehring et al., 2002; Benvenuti et al., 1994). It appears that the first flushes must be removed to prevent further weed population from the seed banks, and planting pattern of the crops should be considered as well.

For both soybean planting patterns an increase in weed mass were observed, with the increase of dry matter in each plant, seed production was raised (Figure 2). For this reason the mean of seed numbers in the remaining plants at the end of the seasons' growth for the first flush were measured. Higher seed production in each velvetleaf bush in the wide-rows can be correlated to the differences in biomass and percentage of mortality in both planting patterns. It was used a simplest linear model for calculation of the seed productions where the independent variable was the weight of each plant (Mertens and Jansen, 2002). Intercept of regression model for seed production was increased when seedling size rose, this situation was seen in the wide-rows. For this reason the number was 181 in the wide rows spacing (as it was compared to 102 in narrow-rows). Similar trends were seen during various other studies, such as the effect different row spacing's for wheat on the seed production in a three weed species study (Mertens and Jansen, 2002).

The treatments in this study demonstrated that the narrow – row spacing resulted in less seed production and bigger seedling mortality. Dry matter and seed production was estimated for each plant (as an alternative of per area unit). This method has some advantages. At first, it revealed the weed community increase or decrease. Moreover, the velvetleaf population had no even distribution in the field. Therefore we should not compare our results on the dry matter and seed density of velvetleaf with those obtained per unit area, the comparisons would have been incorrect.

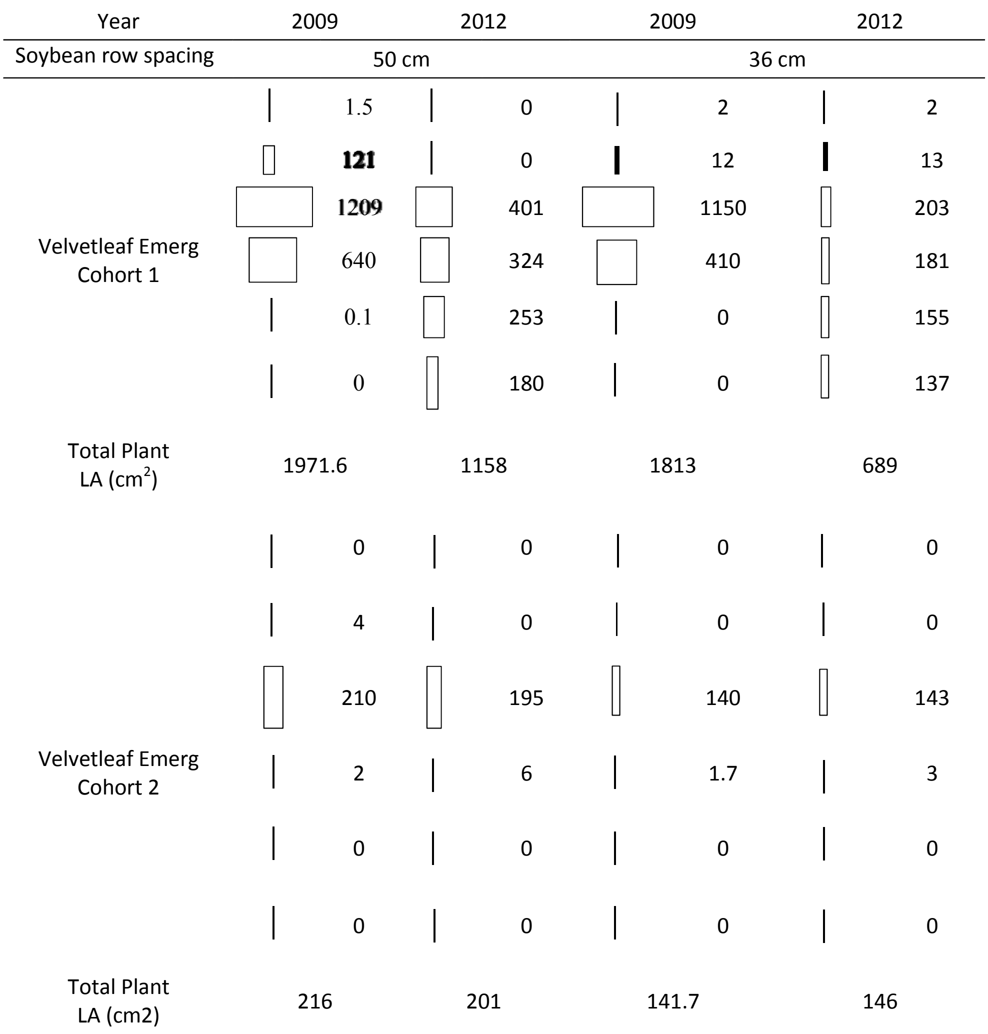

Figure 1: Velvetleaf leaf area (LA) distribution at soybean maturity for years 2009 and 2012 as influenced by crop row spacing and time of velvetleaf emergence in velvetle af-soybean plots. Each rectangle represents a 40 – cm height increment. Total LA is shown at the bottom each symbolic plant.

This study emphasizes the importance of integrated weed management through the method of weed emergence control time and using an inexpensive planting patterns. Furthermore, the data on leaf area, total of dry matter and seed production also suggested the greater need for control of early emerging rather than late-emerging velvetleaf of populations.

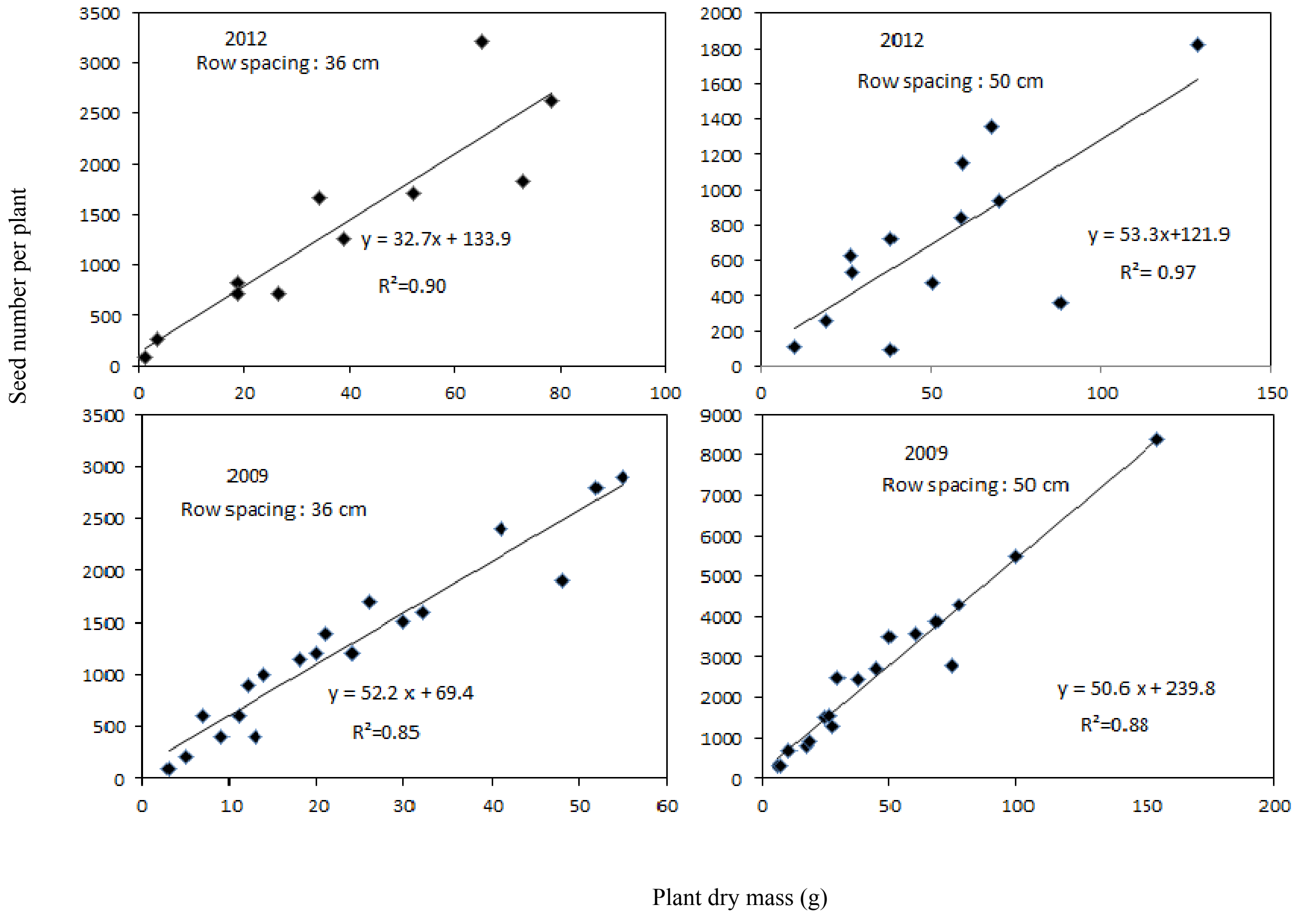

Figure 2: Relationship between the number of seeds produced by velvetleaf plant and plant dry mass in various soybean planting patterns for years 2009 and 2012

4 CONCLUSIONS

A long term integrated weed management plan should be considered for early control of the velvetleaf population rather than the late-emerging population. The data collected in this study on the leaf area, total dry matter and seed production confirm the need for better control techniques of the velvetleaf population. Furthermore, this study has demonstrated a necessity for further studies and research for successful results such as reduction and effective control of the weed seed stocks in the soil. These methods and techniques would not degrade the environment, quality of the land or agricultural crops and most of all it is very important their cost effect.

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