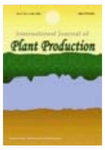

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Changes in weed seed banks and the potato yield as affected by different amounts of nitrogen and crop residue

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Abstract

In order to evaluate the impact of crop residues (zero, 25 and 50%) and nitrogen (zero, 125 and 250 kg ha) on weed seed bank and potato yield, two-years research was conducted as a split plot arranged in randomized complete block design in Rozveh Agriculture Research Station, Freidan-Esfahan. Numbers of weed species in seed bank, aboveground, and both seed bank and aboveground were 1, 2 and 8 respectively. *Amaranthus retroflexus* L. was dominant weed in seed bank in the both years. Weed seed bank was significantly lower in both N rates than control in the both years with no significant difference between the rates. Weeds biomass with increased use of nitrogen fertilizer increased. In 25 and 50 percent of crop residue treatments, weed seed density was greater than control. 125 kg N ha^{-1} with 25 percent of crop residue treatment produced the highest tuber yield (27850 kg ha^{-1}), although weed biomass was also high in this treatment. The results showed that management of nitrogen fertilizer application and weed control by applying crop residue crops in rotation will change.

Keywords: Redroot pigweed (*Amaranthus retroflexus* L.); Seed; Incorporation; Weed biomass.

Introduction

Soil weed seed bank is an important component of weeds problem in agroecosystems and lead to negative impact on the crop production (Buhler et al., 1997). Weed management implies a shift away from strict reliance on control of existing weed problems and place greater emphasis on reduction of weed emergence in a crop (Zimdahl, 2011). The term of soil weed seed bank refers to vital weed seeds exiting in topsoil (Feng et al., 2008). Numbers of seed in soil seed bank in agricultural zone different from near zero to as much as one million seeds m^{-2} (Fenner, 1985). However in agroecosystems with different crop rotations, the evaluation of separated seeds of mother plants, in a multi-year period are more important (Albrecht, 2005). Nitrogen fertilizer is commonly accepted as a key component for crop production. Positive correlation between nitrogen application (NO^{-}_{3} or NH^{+}_{4}) and germination of many weed seed reported by previous research (Benech-Arnold et al., 2000). For example, Bungard et al. (1997) observed that increased germination (10-12%) in *Clematis vitalba* L. species when applied 2.5 mM NO^{-}_{3} or NH^{+}_{4}. Hilhorst and Karssen (1990) suggested that influence of light, and more specifically the active form of phytochrome, on germination is commonly correlated to the presence of NO^{-}_{3}. However, in most studies, such as Davis (2007), the effect of nitrogen addition on seed germination is conducted in green house.

The use of organic matter application (compost or crop residue) has increased during the many past decades but little information is available on their effects on soil weed seed bank. Only the few previous studies evaluate effect of the organic matter application as useful approach for weed seed bank management (Chee-Sanford et al., 2006; Davis, 2007). Soil C: N ratio is an important index for assessment of crop residue quality. Chee-Sanford (2006) found that seed coats of many weed species have higher C: N ratio than others and may be decrease rapid deterioration of the seed. Davis (2007) reported significant impacts of corn stover on seeds of one of eight annul weed species. Among the eight weed species studied, addition corn stover rate (0 and 3000 mg stover kg $soil^{-1}$) decreased velvetleaf seed mortality by 40% than in the unamended treatment.

Residue incorporation can improve physical and biological conditions of the soil therefore can increase nutrient absorption (Nyborg et al., 1995), but when the amount of plant residues mixed with soil is high (particularly with high C: N), N uptake by plants is reduced (Burgess et al., 2002). Adding organic matter to the soil, can change the activity of microorganisms, weed seed germination and weed seedbank (Webster, 2003). Due to the recent tendency farmers to use crop residue in crop rotation has increased, this study was conducted to determine the variations of soil weed seed bank, weed biomass and potato yield as affected by crop residue amended and N application in different rates.

Materials and Methods

This field experiment was conducted at Rozve Experiment Station, at Agricultural and Natural Resources Research Center (32° 50´ N, 50° 34´ E), Isfahan, Islamic Republic of Iran, 17 km north of Eastern of Chadegan in two cropping seasons (2010-2011) on a sandy loam soil. In rotation, before the potato planting, wheat (Back Cross cultivar) was cultivated. Characteristics of the soil and climatic conditions of the experiment are shown in Table 1 and Figure 1, respectively. Climatic data obtained from weather station in Daran city.

Table 1. Soil selected characteristics for site of experiment.

Soil characteristics	Measurement
Sand (%)	14.4
Silt (%)	41.2
Clay (%)	44.4
Electrical conductivity (dS m^{-1})	3.78
pH	7.7
K (mg kg^{-1})	410
P (mg kg^{-1})	26
N (%)	0.06
Organic matter (%)	0.55
Bulk density (g cm^{-3})	1.30
C:N ratio in crop residue	85.5:1

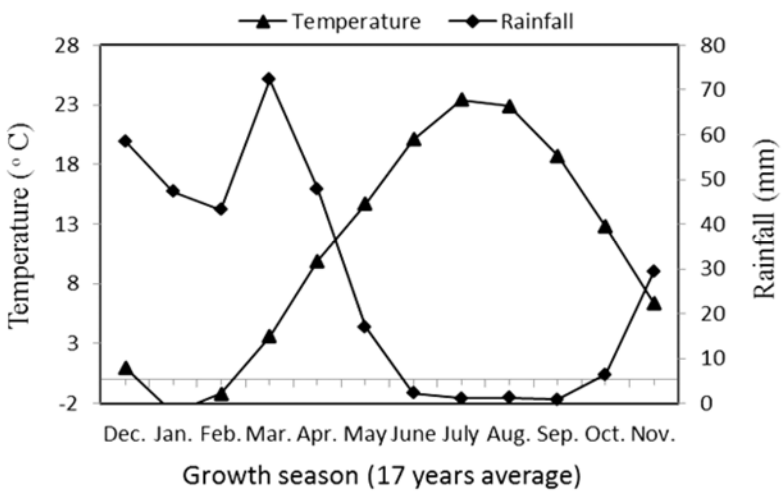

Figure 1. Average of rainfall and temperature measured for 17 years.

The experiment was conducted as a split plot arranged in randomized complete blocks design with three replications. Treatments consisted of three N levels (0, 125 and 250 kg ha^{-1}) as main plots, and three residue incorporation levels [0 (control), 25 and 50% of wheat residues] as subplots. N fertilizer was applied as urea (46% N) which for the treatment of 125 kg N ha^{-1}, 30 percent of fertilizer was applied before planting, and 40% at hilling period (approximately 35 days after planting) and 30% at tubers developing stages. For the treatment of 250 kg N ha^{-1}, the amount of N fertilizer consumed in preplanting, hilling period, and tubers developing stages were 20, 40 and 40%, respectively. According to soil test, P and K was not essential.

The average irrigated wheat residues cover determined by random throwing of 0.25 m^{-2} frames after harvesting was 5.0 Mg ha^{-1} in the both years and had been incorporated into a depth of 10-12 cm by a light disc prior to planting. Approximately, adding plant residues 1375 and 2750 kg ha^{-1} respectively for 25 and 50% mixing crop residue. Potato (CV. Agria) was planted in plots 1.5×6 m in June 20 and harvested in the middle of October in the both years. Row and plant spacing's were 75 and 20 cm, respectively. Irrigation (furrow) was applied when the soil moisture in the root zone declined to 60-65% of field capacity. To determine the irrigation time the tensiometers placed at 15 and 30 cm depths responded to changes in soil water. To measure the tuber yield (after eliminating the edges), the whole tuber yield was measured on each plot. Tubers with size less than 35 mm were considered as non-sales tuber yield.

Soil sampling (six soil sample cores from the center of each plot) for seed bank was carried out with an auger 2.5 cm in diameter and 20 cm deep. Sampling in the first year before planting, and in the second year after harvesting (from 15 to 20 October) was conducted. In order to separate seeds from soil, soil from each core was maintained for 18 h in 800 ml 0.5% sodium hexametaphosphate solution (50 g L^{-1}) (Calgon solution) (Makarian et al., 2007). The suspension was passed through two sieves (sieves mesh size were 0.5 and 0.2 mm in upper and lower, respectively). Light weight seeds floating on the surface of the suspension were discarded. The material (seeds + debris) retained by the sieve was then transferred to filter paper and air dried. Weed seeds were counted and identified by species under a magnifying glass (×10). To determine the role of weeds in reducing crop yield, when weeds reached the maximum biomass, weed biomass was measured before harvest. For this reason, in each plot, weeds were cut from the soil surface and placed in the oven for 48 hours.

The data were subjected to analysis of variance by SAS (SAS Institute, 2007) and means Duncan's test was used for mean separation. Actual data were transformed [log (y+1)] before ANOVA to increase homogeneity of error variances (Steele and Torrie, 1980).

Results and Discussion

Presences of 11 weed species have shown in Table 2. Among the weed species, 8 species were presented in the both seed bank and aboveground. Only one species of weed (wild oat) was found in soil seed bank, and two weed species were observed only on the aboveground. *Amaranthus retroflexus* was dominant weed in seed bank in both years (51 and 70% respectively). The number of grass and broad leaf weeds in soil seed bank were 18 and 82%, respectively. History of farming land shows that grass control herbicides widely used in crop rotation while the range of broadleaf herbicides in rotation is more limited. This could be a reason for the difference of the grass and broad leaf weeds percentage. Averagely, another weed species with high seed abundant were *Chenopodium album* L. and *Heliotropium spp*. Two weed species of *Polygonum aviculare* L. and *Sonchus oleraceus* L. were not existed in seed bank in the both years. Distribution of weed seeds in the soil is heterogeneous, so the seeds of some weeds may not be found in the soil sample, but are growing in the aboveground. These weed species often have little participation in the total biomass of weeds. However, heterogeneous field conditions are inherent in most agricultural fields and this heterogeneity can be manifested in weed communities (Rew and Cousens, 2001). In some previous studies, the weed population emerging after cultivation was related to the size and composition of the weed seedbank (Zhang et al., 1998). But in other studies, no relationship was found between weed seedbank and aboveground communities (Derksen and Watson, 1998), or only for a small number of species (Webster et al., 2003). Generally, seed banks are composed of many species, with a few dominant species comprising 70 to 90% of the total seedbank (Wilson, 1988). In this study *Amaranthus retroflexus* was dominant weed in seed bank (Table 2). In a study that was conducted in northern Greece to evaluate effects of tillage regime, cropping sequence and herbicide treatment (Vasileiadis et al., 2007) found that *Amaranthus* spp. and *Portulaca oleracea* were the most abundant species with ranging from 76 to 89% of total weed seeds and more weed species that were existed in the aboveground were also existed in seed bank. Vasileiadis et al. (2007) reported that 60% of weed species were existed both aboveground and soil seed bank. Adversely, Derksen and Watson (1998) reported that there is no relationship between weed seedbank and aboveground communities. Webster et al. (2003) found that a relationship, only for a small number of species. However, in present study, *Avena fatua* L. was found only in soil seed bank while the two species *Polygonum aviculare* L. and *Sonchus oleraceus* L. were found only in aboveground. Only one perennial weed (*Convolvulus arvensis*) and one biennial weed (*Lactuca spp*) were existed in seed bank (Table 2). It was to be expected, usually in intensive farming systems, tillage operations are performed frequently, and perennial weeds reduced (Barberi, 2002).

Table 2. Weed species identified in the soil seed bank and aboveground flora.

Scientific name	Common name	Presence	Life cycle	Number of seeds in the seed bank (1000 m^{-2})		%Seeds in seed bank	
				2010	2011	2010	2011
Setaria spp	Foxtail	S-A	An	2.0	0.73	4	1.5
Chenopodium album L.	Common lambsquarter	S-A	An	8.9	8.8	18	15
Avena fatua L.	Wild oat	S	An	1.5	0.73	3	1.5
Amaranthus retroflexus L.	Red root pigweed	S-A	An	25.4	34.0	51	70
Convolvulus arvensis	Filed bindweed	S-A	Pe	2.5	1.21	5	2.5
Polygonum aviculare L.	Knotgrass	A	An	-	-	-	-
Sonchus oleraceus L.	Smooth sow-thistle	A	An	-	-	-	-
Rumex crispus	Curly dock	S-A	An	1.5	0.49	3	1
Lactuca spp	Wild lettuce	S-A	B	2.5	1.21	5	2.5
Heliotropium spp	Heliotrope	S-A	An	3	1.46	6	3
Carthamus spp	Wild safflower	S-A	An	2.5	1.46	5	3

Pe, perennial; An, annual; B, biennial; S, seed bank; A, aboveground; S-A, present in both seed bank and aboveground.

Seed density and weed biomass were significant differences at two-year study, but no significant difference was observed between the two years of study for total and non-sales yield (Table 3). The main reason for the difference in biomass and soil seed bank of weeds in two years of study was time of sampling. The sampling time was at the first and second years, respectively, before planting and after harvest. The time of sampling of soil for the study of the seed bank is an important factor influencing the results obtained (Roberts, 1981). Sampling time, management and differences between the persistence of seeds of different species in the soil seed bank were responsible for the large differences between the composition of the vegetation and seed bank (Lopez Marino et al., 2000).Weed seed bank was significantly lower at the both N rates than control in the both years with no significant difference between the rates (Figure 2 A and B). Weed seeds density were significantly higher in the second year than the first year in the soil seed bank. The size of the seed bank can change in a short period (2 or 3 years) because of seed losses and inputs to the seed bank (Buhler et al., 1997). N application increased seed germination at the both in agroecosystems (Hendrickson and Taylorson, 1974; Hilhorst and Karssen, 1990; Bungard et al., 1997) and in natural ecosystems (Kitajilma and Tilman, 1996). Increasing of seed germination, especially in *Amaranthus* species as affected by N application was reported in some studies (Teasdale and Mohler, 2000; Teasdale and Pillai, 2005).

Table 3. Combined analysis of variance for total yield, non-sales yield, weed biomass and seed density as affected by nitrogen application and crop residue incorporation.

Source	df	Total Yield (kg ha^{-1})	Non-sales yield (kg ha^{-1})	Weed biomass (kg ha^{-1})	Seed density (1000 m^{-2})
Year	1	8513509^{ns}	2320184^{ns}	1862802**	67654897**
Replication (Year)	6	1201567	2113644	70587	6543214
Crop residue (%)	2	431000150**	300214310**	12345*	786543212*
Crop residue (Year)	2	3114699^{ns}	1123560^{ns}	142146^{ns}	6543287^{ns}
Error	12	4222440	1255140	435325	7689432
Nitrogen	2	4344111**	1321520**	156432**	8675432
Nitrogen (year)	2	80234675^{ns}	6000784^{ns}	4543223^{ns}	7654006^{ns}
Nitrogen × Crop residue	4	13456101**	8564567**	7665423*	16789654*
Nitrogen × Crop residue (Year)	4	43986990^{ns}	13245600^{ns}	8767655^{ns}	98732123^{ns}
Error	36	1234618	2756410	1239873	2345009

* and ** Significant at %5 and %1 level of probability, respectively. ^{ns} not significant.

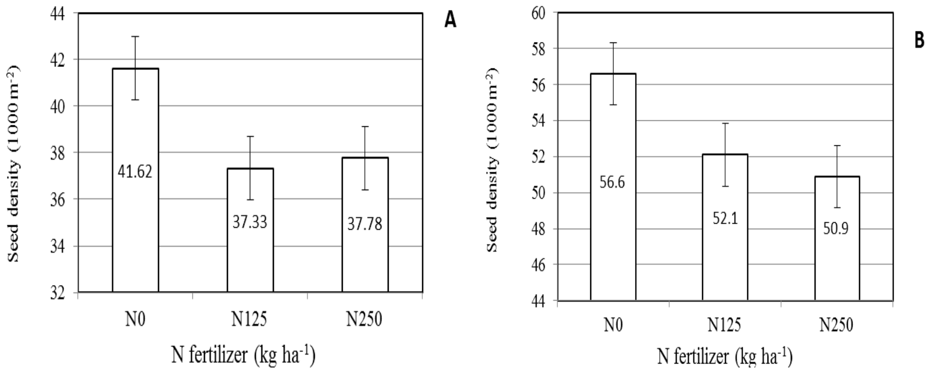

Figure 2. Effect of N fertilizer on weed seeds in soil seed bank for two years, (A) 2010 and (B) 2011. Column with similar letters are not significantly different (P=5%).

Weed biomass increased with increased nitrogen application (Figure 3 A and B). *Amaranthus retroflexus* L. was dominant in the first year of the study, but the total biomass of other weeds was greater than *Amaranthus retroflexus* L. biomass. In the first year, the percentage of contribution *Amaranthus retroflexus* L. biomass, compared to the total weed biomass in control, 125 and 250 kg N ha^{-1} treatments was 31, 38 and 40.5 respectively (Figure 3A). For the second year, these percentages of contribution were 42, 57 and 57 respectively (Figure 3B). Some of the weeds are considered the major consumers of nitrogen (Hans and Jhonson, 2002), therefore may reduce the nitrogen available to crops. Weeds not only reduce the amount of N available to the crops, but also the growth of many weed species are enhanced by higher soil N levels (Blackshaw et al., 2003).

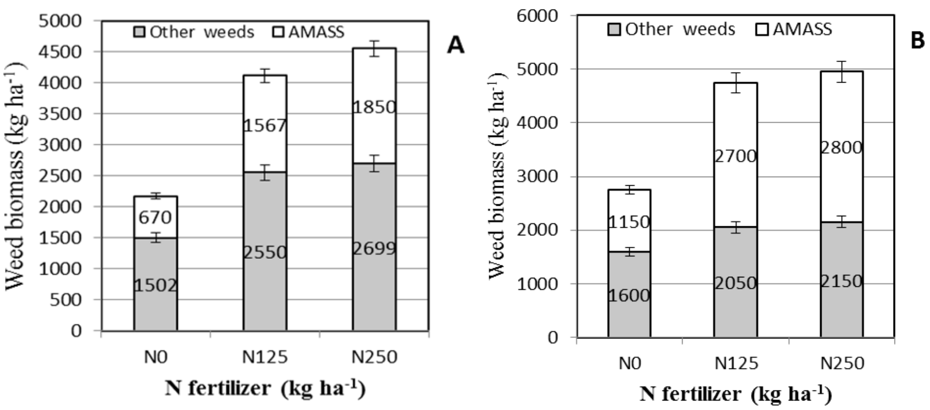

Figure 3. Effect of N fertilizer on weed biomass for two years, (A) 2010 and (B) 2011.

Different treatments of crop residue incorporation had significantly effect on weed seed density in the soil seed bank and weeds biomass (P=5%) (Table 3). In the first year, incorporation of crop residues in soil had no effects on the weed seedbank (Table 4). However, a necessary condition for the impact of crop residue, is the decomposition of crop residue, and one year is little time for this case. In the first study, the number of weed seeds in the soil seed bank were 54600 and 52900 in 25 and 50 percent of crop residue incorporation treatments in which there were no difference with control (53200 weed seeds). In the second year, 25 and 50 percent of crop residue incorporation, increased seed density 20.7 and 11.3 percent respectively in comparison with control, but there was no significant difference between the two treatments (Table 4). In this year, the number of weed seeds in the two treatments of 25 and 50 percent of crop residue incorporation were 65500 and 62000 respectively, which was significantly higher than control (54700 weed seeds). Three years after conversion of conventional to organic farming system Albrecht (2005) found that total seeds number in the soil increased from 4050 to 17320 m^{-2}. Crop residues with high C: N ratios were effective in soil nitrate uptake (Liebman and Davis, 2000) and therefore decreased the role of N in seed germination. In first and second years, incorporation of crop residue to the amount of 25%, weed biomass was increased relative to the control 16.5 and 18.2 percent, respectively. Increasing the amount of crop residue incorporation to 50%, weed biomass in the first year was reduced but did not significantly different in the second year. Relationship between the amount of crop residue and weed biomass, have been less investigated. Teasdale (1998) believed that, although there were many reports on weed suppression by plant residue and mulches, not many have assessed the quantitative relationship between residue and weed emergence. Phytotoxic effects of crop residues, delayed patterns of N availability, and incidence and severity of soil-borne diseases affecting weeds and crops are reasons to change the amount of weed biomass due to crop residue incorporation (Liebman and Davis, 2000). In comparison three types of plant residues to control weeds (sunflower, soybean and corn), type of crop residue had no effect on weed control but when the crop residue increased from 6 to 24 t ha^{-1}, increased control of weeds (Barker and Bhowmik, 2001). However, although the presence of crop residue can negatively affect on the growth of some weed species but most of the weeds, even in the presence of crop residue can have high growth and reduce crop yield (Radosevich et al., 1997).

Table 4. Effects of crop residue incorporation on seed density, weed biomass, and the total and non-sales yield of potato.

Treatments	Seed density ($1000\ m^{-2}$)		Weed biomass ($kg\ ha^{-1}$)		Total yield ($kg\ ha^{-1}$)	Non-sales yield ($kg\ ha^{-1}$)
Crop residue (%)						
	Years				Means of 2 years	Means of 2 years
	2010	2011	2010	2011		
0	53.2[a]	54.7[b]	2703[b]	2789[b]	22200[b]	6700[a]
25	54.6[a]	65.5[a]	3150[a]	3300[a]	24960[a]	7050[a]
50	52.9[a]	62.0[a]	2890[b]	2620[a]	19400[c]	6930[a]

Means of each column with similar letters are not significantly different (Duncan's 5%).

Interaction of crop residue incorporation and nitrogen fertilizer on seed density and biomass of weeds was statistically significant (Table 3). Weed seed hulls can be considered a source of nutrition for soil microbes but the weeds that have a hulls with C:N high it will inhibit degradation (Chee-Sanford et al., 2006). In such a case, only the addition of organic matter with C:N ratio lower, can accelerate the decomposition of the hulls and thus reduce soil weed seed bank (Davis, 2007). In the present study there was no such role for crop residue with high C:N ratio (Table 1) but seed density and seed germination was changed with both the nitrogen and crop residue application. In 125 kg N ha^{-1} with 25% crop residue treatment (in both years) and also 250 kg N ha^{-1} with 25% crop residue treatment (only in the second year) soil weed seed bank declined significantly (Table 5). But weed seed bank in soil at 125 and 250 kg N ha^{-1} treatments; in addition to 50% crop residue had no significant difference with control treatment. Apparently, the short term period, if the crop residue is more than a certain amount, even with high levels of nitrogen application, crop residue decomposition is carried out slowly, and the weed seed bank will remain constant. Because of our emphasis on the close relationship between weed seed bank and the amount of soil organic matter added to the soil, is that the amount of soil organic matter in the present study (similar to most parts of the country) is much low (0.5%). Chee-Sanford et al. (2006) also believes that seeds of some species may provide a major source of carbon or nitrogen nutrition for microorganisms seems logical in the absence of other organic matter compounds.

Table 5. Interactions effects of nitrogen and crop residue incroporation on seed density, weed biomass, and the total and non-sales yield of potato.

Treatments		Seed density (1000 m^{-2})		Weed biomass (kg ha^{-1})		Total yield (kg ha^{-1})	Non-sales yield (kg ha^{-1})
		Years				Means of 2 years	Means of 2 years
		2010	2011	2010	2011		
N_1	R_1	53.0^a	55.0^a	2280^d	1900^d	17500^c	4150^b
	R_2	53.5^a	54.2^a	3050^c	2100^c	15540^c	4780^b
	R_3	53.0^a	51.1^a	3000^c	3200^c	15300^c	4580^b
N_2	R_1	52.7^a	53.2^a	3850^b	3690^b	23470^b	4870^b
	R_2	42.9^b	37.1^b	3760^b	4000^b	27850^a	6350^a
	R_3	50.9^a	49.2^a	4200^{ab}	4150^b	22500^b	5100^b
N_3	R_1	40.8^b	42.3^b	4500^a	5050^a	23300^b	4920^b
	R_2	50.8^a	44.5^b	4560^a	4967^a	26020^{ab}	6800^a
	R_3	50.2^a	50.7^a	3830^b	4876^a	22430^b	4200^b

Means of each column with similar letters are not significantly different (Duncan׳s 5%). R_1, R_2 and R_3 are control, 25 and 50% crop residue incorporation respectively and N_1, N_2 and N_3 are control, 125 and 250 kg N ha^{-1}.

The use of 125 kg N ha^{-1} with 25 or 50% crop residue increased weed biomass compared to not using nitrogen fertilizer. Meanwhile, 125 kg N ha^{-1} with 25 percent of crop residue treatment also produced the highest tuber yield per hectare (27850 kg ha^{-1}) (Table 5). Appears to apply adequate nitrogen fertilizer with accelerate mineralization of crop residues may have created suitable conditions for potato production. Some researchers believe that the gradual release of nutrients (particularly nitrogen) from the organic material is more profitable crops compared to weeds (Blackshaw et al., 2005) but some had opposite opinion and believe that in such circumstances weeds are growing faster compared to crop yields (Liebman and Davis, 2000). In the present study, using the highest amount of nitrogen (250 kg ha^{-1}) associated with crop residue (25 or 50%), increased weed biomass, and reduced tuber yield of potatoes. It seems, in the amounts higher than nitrogen required crop, weed the efficient use of excess nitrogen, which are more competitive and reduce the yield of potato. However, increases in both crop residue and nitrogen had no the same effect on the composition of weeds (Figure 4 A and B). *Amaranthus retroflexus* L. was considered dominant in among weeds. *Amaranthus retroflexus* L. biomass alone was several times higher than other weeds. The highest amount of biomass in different treatments after *Amaranthus retroflexus* L. was devoted to *Chenopodium album* L. In some reports, the nitrogen source (organic or inorganic) was effective on the density and diversity of weeds (Mt and

Schlater, 1994). However in most cases, the reason for superiority of the dominant weed species is more efficient use of environmental resources particularly in light adsorption (Pallut, 1993).

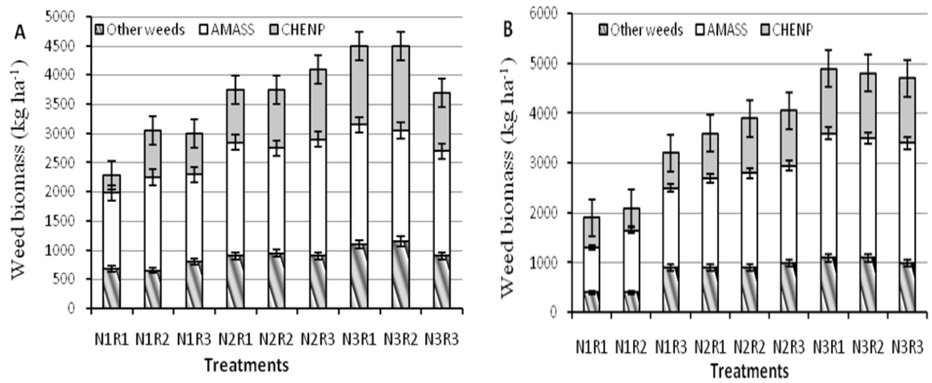

Figure 4. Interaction between crop residue (R_1=control, R_2=25% and R_3=50%) and nitrogen fertilizer (N_1=control, N_2=125 kg N ha^{-1} and N_3=250 kg N ha^{-1}) on weed biomass for two years, (A) 2010 and (B) 2011.

Conclusions

In summary the results of this study showed that the use of crop residue alone does not have a significant effect on soil weed seed bank. Presumably, increased weed biomass in such a case, is related to other effects of crop residue, such as improved soil conditions, allelopathic effects of crop residue and etc. On the contrary, increasing both crop residue and nitrogen fertilizer in the soil had a significant impact on the weed seed bank. In the latter case, the decision about the amount of nitrogen and crop residue and its impact on yield is very important. In the present study 125 kg N ha^{-1} with 25 percent of crop residue treatment produced the highest tuber yield (27850 kg ha^{-1}), although weed biomass was also high in this treatment. Increasing more than 125 kg N ha^{-1} is associated with higher weed biomass, increase N loss and decreases tuber yield. Increasing amounts of higher crop residue (>25%), at least in the short term (one or two years) had similar negative effects on yield.

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