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Effect of Legume and Cereal Mulches on Weed Dynamics and Potato Yield

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ABSTRACT

Background: Non-chemical management methods, including cover crops, has an essential role in diminishing weed infestations and reducing the use of herbicides.

Methods: To evaluate the suppressive effects of four cover crop options on weed populations, a field experiment was conducted in factorial randomized bock design with three replications at Ardabil Agricultural and Natural Resources Research Station, Ardabil, Iran, in 2016. The treatments consisted of legumes and cereal cover crop as one factor (Control, Rye, Common vetch, Grass pea and Hungarian vetch) and crop management strategies as a second factor [forage use (FU) and land cover use (LCU)].

Result: Grass pea sown as fodder use strategy recorded the highest fresh and dry weight of weeds significantly. The greatest potato yield production was observed in Rye and Hungarian vetch plots, approximately 5000 kg ha^{-1} in both FU and land LCU strategies. Generally, it seems that Rye and Hungarian vetch could be acceptable options to use in potato production as cover crops.

Key words: Forage, Hungarian vetch, Rye, Tuber yield.

INTRODUCTION

Sustainable potato production is essentially dependent on controlling weed infestations continuously (Schmidt *et al.,* 2019; Shehata *et al.,* 2019). Weed control strategies in crop production can be divided into chemical and nonchemical practices (Zangoueinejad and Kazemeini, 2014; Azadbakht *et al.,* 2017; Zangoueinejad *et al.,* 2018; Zangoueinejad, 2019; El-Metwally and El-Wakeel, 2019; Nabati Souha *et al.,* 2020a,b; Zangoueinejad *et al.,* 2021). Although various herbicide options are available to control weed abundances in crop fields worldwide (Alebrahim *et al.,* 2011; Khatami Kalkhoran *et al.,* 2017; Zangoueinejad *et al.,* 2019; Alebrahim *et al.,* 2021; Guo *et al.,* 2021). However, cover crops can be considered an effective weed control strategy in sustainable agriculture by reducing the side effects of herbicide use, improving soil quality over time and increasing crop yield production (Barbas *et al.,* 2020).Therefore, due to the destructive effects of herbicides on natural resources, concerns have been raised in recent years (Zangoueinejad and Ghadiri 2014, 2016; Mehdizadeh *et al.,* 2017; Alebrahim *et al.,* 2017; Hashemi *et al.,* 2021; Camargo *et al.,* 2020; Zangoueinejad and Alebrahim, 2021b) leading to an increased attention on their negative effects on the ecosystems, including soil and water pollution and its phytotoxic effects on crops in rotation (Mehdizadeh, 2016; Azadbakht *et al.,* 2019; Khatami Kalkhoran *et al.,* 2017; Zangoueinejad and Alebrahim, 2021a). Over the past years, rising food demands and other environmental concerns regarding herbicide worldwide have forced weed scientists to investigate safer approaches to lessen environmental concerns and effectively manage weed infestations in the agricultural infrastructures simultaneously (Reddy 2003; Abbas *et al.* 2018). One the most effective strategies to achieve this goal is incorporating weed-suppressive cover crops in agricultural systems (Sharifi Ziveh *et al.,* 2019). The use of cover crops could prove to be a desirable alternative to conventional weed control methods increasing crop productivity and sustainability (Maharjan and Jung 2016; Jian *et al.,* 2020; Rostami *et al.,* 2021). Cover crops influence the physical, chemical and biological soil properties along with the emergence and growth of weed populations and finally, crop yield production (Blanco-Canqui *et al.,* 2015). In particular, the legume cover crops improve the soil nutrients by fixing atmospheric nitrogen and decrease the accessibility of inorganic nitrogen crops and dependency on synthetic nitrogen fertilizers (Bilalis *et al.,* 2012; Blanco-Canqui *et al.,* 2015; Stagnari *et al.,* 2017). Besides, legume cover crops are considerable tool to diminish weed invasions

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(Storkey *et al.,* 2015). Various internal and external factors shape the weed suppression power by the legume cover crops, for example: crop species and genotype together, with crop density and composition. Furthermore, management strategies like cutting time can influence the impact of legume cover crops on invasive weed species (Hauggaard-Nielsen *et al.,* 2006; Gottshall *et al.,* 2017). There are two main ways to use legume cover crops in agricultural systems (Hiltbrunner *et al.,* 2007; Lorin *et al.,* 2015). First, growing these species when the major crop is still not cultivated (Papp *et al.,* 2018; Elsalahy *et al.,* 2019). Second, using legume cover crops in the form of living mulches by intercropping them with the main crop for only a part of the growing season (Papp *et al.,* 2018; Elsalahy *et al.,* 2019). Remarkably, legume cover crops block or postpone the germination of weeds and interfere with the development of weed flora by establishing instantly and subsequently occupying all niches to reduce the competition strength of weed species (Ranaivoson *et al.,* 2017).

In this current study, we aimed to test the weed suppression capability of three legume species, including common vetch (*Vicia sativa* L.), grass pea (*Lathyrus sativus* L.), Hungarian vetch (*Vicia pannonica* L.) and Rye (*Secale cereal* L.) a well-known cover crop worldwide as potential cover crops in potato processing. In addition, the effects of the legume cover crops on the potato yield production were compared with that of rye.

MATERIALS AND METHODS

The experiment was conducted at the Research Station of the Iran Agricultural and Natural Resources Research Organization, Ardabil Province Branch (Arallou), 48°23′ 35.4″ E, 38°10′21.5″N, altitude 1390 MSL, in 2018. The physical and chemical soil properties of the experimental site are: organic carbon, 1.02%; loam soil texture; salinity, 0.874 ds/m; K, 318 ppm; P, 5.58 ppm; N, 0.1%; Clay, 25%; Silt, 72%; Sand, 45% and PH, 7.79 (Table 1).

The experiment was laid out in a factorial randomized complete block design with three replications. The treatments consisted of a mulch of cover crops, including common vetch, Rye, grass pea, Hungarian vetch and control (without mulch), as one factor and crop management strategies including forage use mulch (FU) and land cover use (LCU) as the second factor. Cover crops were sown and harvested before cultivating the main crop when they were used as the forage mulch, while they were intercropped within the main crop, as living mulches. Rye, common vetch, grass pea and Hungarian vetch were planted using a seed rate of 180, 120, 120 and 100 kg ha^{-1}, respectively. The cover crops were allowed to grow at the time of planting potato as the main crop and then the management treatments were carried out. Potato planting was performed using a fully automated planting machine with a seed rate of 53,000 plants ha^{-1}. Cover crop management treatments were applied after cultivating potato tubers. The fresh weight of the weeds and cover crops was measured and then plant samples were dried at 75°C for two days and subsequently weighed. The number of weeds was counted in two stages. The first stage was before harvesting the cover crops in both management strategies and the second one was at 45 days after emergence. The species diversity index was calculated using the Shannon-Wiener index, as follows:

$$H = - \sum [P_i \times \ln (P_i)]$$

Where,

H = The Shannon-Wiener index.

P_i = The division of the number of ith weed species to the total weed species number.

All analyses were executed using SAS version 9.4 (SAS Institute, Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

Weed species density and identification

The experiment was severely infested with wall barley (*Hordeum murinum*), foxtail millet (*Panicum italicum* L.), redroot pigweed *(Amaranthus retroflexus* L.) and Germander speedwell (*Veronica chamaedrys* L.) showed the highest density (Fig 1). The majority of the weed species were annuals and some of them were perennials (Table 2; Fig 1). Generally, cover crops reduced the growth of the perennial weed species (white top, milk thistle, yellow salsify, Russian knapweed, *etc.*) through shading. In contrast, four important weed species in this experiment (barley grass, foxtail millet, redroot pigweed and Germander speedwell) were annuals. This might have happened due to the faster initial growth of weed, where they would quickly occupy the niches in the field and consequently be able to prevent the regrowth of perennial weed species.

Weed fresh and dry weights

Data depicted in Fig 2 revealed non-significant difference between the fresh weight of common vetch and grass pea, under the LCU, as the highest weed fresh quantity. However, the mulch of Hungarian vetch recorded significantly lowest fresh and dry weight of weeds. In the field under forage use, the mulch of grass pea recorded significantly the lowest (Fig 2). The mulch of grass pea in forage use recorded the lowest fresh and dry weight of weeds among other treatments under both management strategies (Fig 2).

Cover crops *via* high biomass production result in a faster canopy closure and subsequently outcompete the

Table 1: Physical and chemical properties of the field soil.

Organic carbon (%)	Soil texture	Salinity (ds/m)	K (ppm)	P (ppm)	N (%)	Clay (%)	Silt (%)	Sand (%)	PH
1.02	loam	0.874	318	5.8	0.1	25	72	45	7.79

Table 2: Recorded weed species in the experimental plots.

Latin name	Scientific name
Barley grass	*Hordeum murinum*
Foxtail millet	*Alopecurus* spp.
Redroot pigweed	*Amaranthus retroflexus* L.
Germander speedwell	*Veronica chamaedrys*
Field bindweed	*Convolvulus arvensis* L.
Flixweed	*Sisymbrium officinalis* L.
Russian knapweed	*Acroptilon repens*
Knotgrass	*Polygonum aviculare* L.
Common lambsquarter	*Chenopodium album* L.
Oat	*Avenafatua*
Shepherd's purse	*Capsella bursa-pastoris*
Italian bugloss	*Anchusa italica*
Milk thistle	*Silybum marianum*
Prickly lettuce	*Lactuca scariola*
Yellow salsify	*Tragopogon dubius*
Pheasant's eye	*Adonis* spp.
Whitetop	*Lepidium draba*

weed populations (Linars *et al.,* 2008; Tokasi *et al.,* 2008). It was reported that rapeseed and Ryegrass showed the most effective weed suppression effects and indicated the lowest proportion of weed dry weight compared to hairy vetch, subclover, snail medick and ryegrass (Campiglia *et al.,* 2009). Among the four cover crops, winter rye and ryegrass were found effective in reducing weed density of 20 plant m^{-2} (Madsen *et al.,* 2016). Consequently, this mulching material reduced the dry biomass of weed populations up to almost 5 g m^{-2}, being the best mulching option to suppress weed population growth (Madsen *et al.,* 2016). Rye/canola, triticale, hairy vetch, hairy vetch/rye, rye, turnip/radish recorded the highest weed control efficiency (90%) as compared to without mulch (Mehring *et al.,* 2016).

Cover crop dry weight

Rye and common vetch recorded the highest and lowest dry weight by 745 and 240 g m^{-2}, respectively, in the LCU management strategy (Fig 3). In the FU management strategy, rye displayed the driest weight of up to 530 g m^{-2} (Fig 3). Generally, results from Fig 3 also illustrated that the

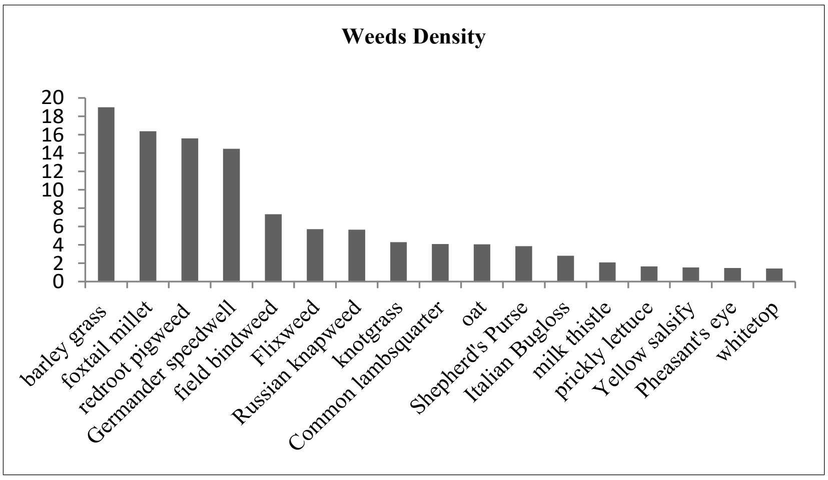


Fig 1: Weed density average and their diversity in the experimental plots.

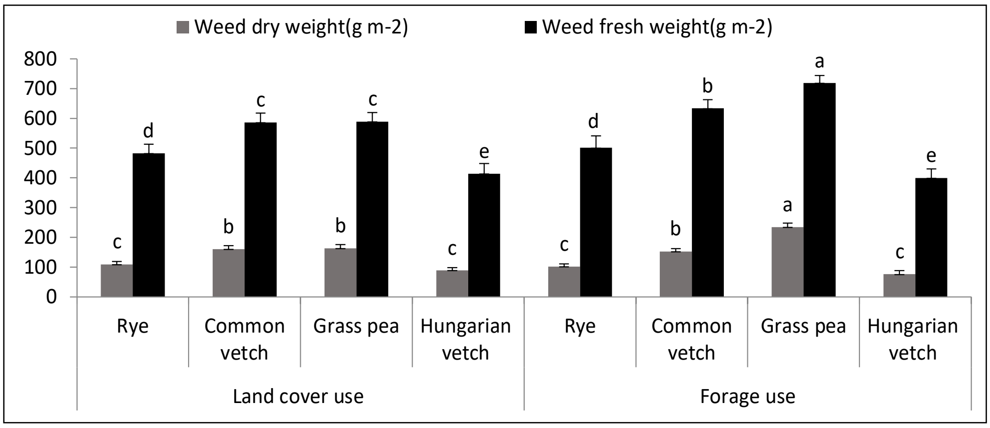


Fig 2: Comparison of weed dry and fresh weights in both management strategies.

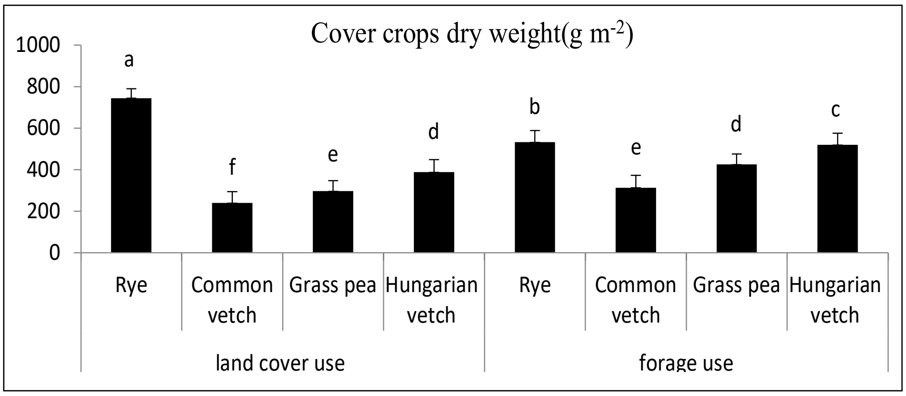


Fig 3: Comparison of the cover crops dry weights in both management strategies.

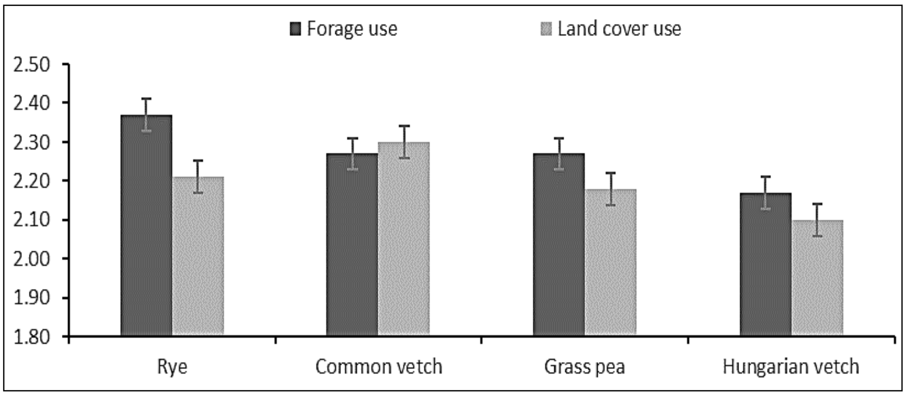
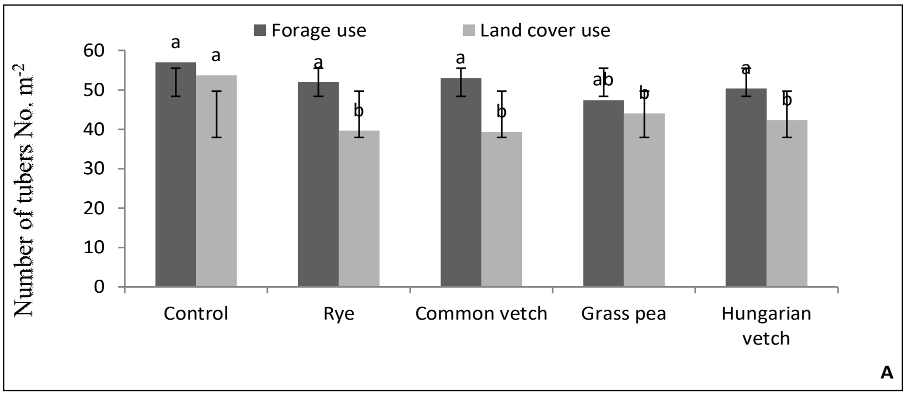


Fig 4: Shannon-Wiener species diversity index in both cover crops management strategies.



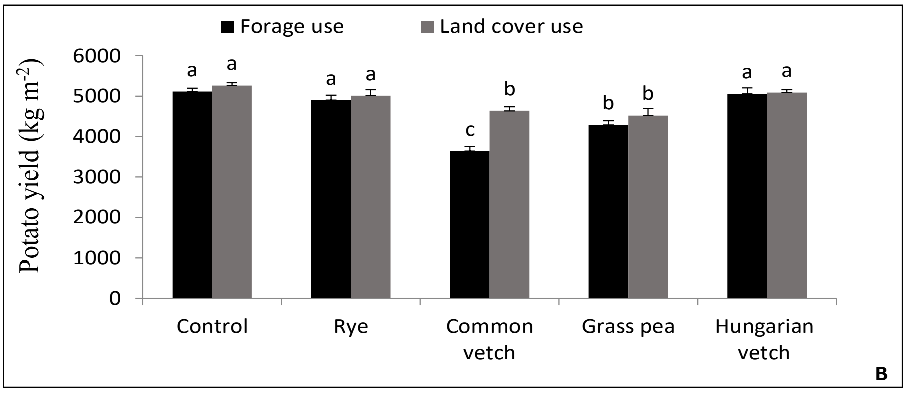


Fig 5: The potato tuber number (A) and tuber yield production (B) in both management strategies.

most cover crop dry weight was recorded for rye in the LCU management strategy compared to all other cover crops in both management strategies; because rye starts to grow faster due to its resistance to extremely low temperature and is more successful in high biomass production. Rye/canola, triticale, hairy vetch and hairy vetch/rye demonstrated the highest dry weight compared to rye, turnip/radish and hairy cover crops (Mehring *et al.,* 2016).

Species diversity index

The highest diversity index value was recorded for rye by 2.37 in the LCU strategy and the lowest was registered for Hungarian vetch up to 2.1 in the FU strategy. These indexes show good species diversity in terms of weeds, although there was no significant difference between cover crops (Fig 4).

Number of tubers

The FU management strategy, there was no significant difference among all treatments, including control and cover crops in terms of potato tuber number per square meter (Fig 5A). However, in the LCU management strategy, the absence of mulch resulted in significantly higher tuber number than in the presence of cover crops; but the difference among cover crop treatments was not statistically different (Fig 5A).

Potato yield

In both strategies, the control treatment recorded the highest potato tuber yields (5300 kg ha^{-1} in LCU and 5100 kg ha^{-1} in FU strategy) (Fig 5B). Although these there were no differences between Hungarian vetch (4900 kg ha^{-1}) in the FU strategy and Hungarian vetch (5055 kg ha^{-1}) in the LCU strategy (Fig 5B). The highest potato yield was recorded after terminating cover crops using roto-till compared with disk-till or herbicide (Mehring *et al.,* 2016). Mehring *et al.* (2016) concluded that cover crops could be an acceptable option to diminish weed invasions or ameliorate potato yield production.

CONCLUSION

Based on the results of four cover crops, rye and Hungarian vetch could significantly reduce the weed dry biomass more effectively than common vetch and grass pea. Although the management strategies were different in terms of the maximum quantity of weed fresh weight and weed dry weight, there was no significant difference between the FU and LCU management strategies in the minimum weed fresh weight and weed dry weight recorded. Importantly, all four cover crops including, rye, common vetch, grass pea and Hungarian vetch, displayed the same effect to enhance the potato tuber number as the control plots. However, only Hungarian vetch and rye demonstrated a significant difference in potato yield production compared to control plots in both management strategies. Therefore, it seems that rye and Hungarian vetch would be acceptable and advisable options to use in potato production; although Hungarian vetch accumulated less biomass than rye. This explains that Hungarian vetch with lower biomass accumulation than rye could be a better option for weed management in potato production because it is a weaker competitor for the main crop. Additionally, Hungarian vetch performed the best compared to common vetch and grass pea, like other legumes, either diminishing weed infestations or ameliorating potato yield production concomitantly.

Conflict of interest: None.

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