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Full Length Article

Use of Mulches for Managing Field Bindweed and Purple Nutsedge, and Weed Control in Spinach

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Abstract

Field bindweed (*Convolvulus arvensis* L.) and purple nutsedge (*Cyperus rotundus* L.) are among the most noxious weeds of the world that infest several field crops and cause huge yield losses. Spinach (*Spinacia oleracea* L.) is an important leafy vegetable that is heavily infested with weeds. Two studies were conducted to assess the organic and inorganic mulches for control of field bindweed and purple nutsedge, and weed control in spinach. In the first study, the efficacy of mulches was evaluated to control field bindweed and purple nutsedge during spring and summer seasons. Mulches tested were: thick and thin black plastic, craft paper, card-board, woodchip and wheat straw mulches. A second experiment was conducted for non-chemical weed control in spinach. Treatments included: two controls *i.e.*, non-treated (no mulch; weedy-check) and weed-free, and three mulches, *i.e.*, thin plastic, craft paper, and wheat straw. All mulches provided effective (>90%) control of field bindweed except the wheat straw that had suppressed the weeds by 76.2%. Weed height, seedling fresh weight, and seedling dry weight of field bindweed were also suppressed significantly by all the mulches. Thick black plastic completely suppressed the purple nutsedge while rest of the mulches provided a >90% control of the weed except wheat straw that suppressed it by 57.8%. Weed-free treatment had the highest spinach crop cover (65.0%) while weedy treatment (no weed control) had the lowest crop cover (30.0%). The highest weed control in spinach was provided by thin black plastic mulch (90.0%) followed by craft paper mulch (83.0%) while wheat straw mulch was least effective with a 49.0% control of weeds. In conclusion, both inorganic and organic mulches were effective for weed control in spinach and suppressing the two troublesome weeds *i.e.*, field bindweed and purple nutsedge. Nevertheless, the wheat straw mulch had the lowest weed control efficacy in both the studies.

Keywords: Crop losses; Field bindweed; Purple nutsedge; Non-chemical control; Noxious weeds; Spinach

Introduction

Human existence on the earth is dependent on constant and sustainable food supplies. Nevertheless, there are several factors that damage field crops and their productivity, and hence disturb the global food security (Gregory *et al*. 2009). Weeds are the most important among such factors and heavily damage the growth, development and productivity of field crops (Lobell *et al*. 2009). For example, weeds were found to have a potential to cause a 37, 23, 30, 40, 36 and 37% decline in the productivity of rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), potato (*Solanum tuberosum* L.), maize (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), and soybean (*Glycine max* L.) on a global scale (Oerke 2006).

Field bindweed and purple nutsedge take place among the most damaging and difficult-to-control weeds globally. For instance, field bindweed is a deep-rooted plant with a perennial growth habit, and its underground rhizomes help the weed to cover the soil surface. Both of its rhizomes and roots possess regenerative characteristics when the plant is in growing phase and each plant of field bindweed may produce more than 500 seeds that are mostly viable. Currently, field bindweed invades several parts of the world and is a serious threat to the productivity of several field crops (Davis *et al*. 2018). Some herbicide application options are available for the pre-emergence and post-emergence control of field bindweed, however, the quest for organic farming and lowering the environmental pollution makes the non-chemical control options more attractive (Davis *et al*. 2018; Orloff *et al*. 2018). Post-emergence control of the weed is difficult because the herbicides or soil cultivation (mechanical control) do not completely kill the weed, and it regenerates after a few weeks of the control practice. Purple nutsedge weed usually propagates through rhizomes and tubers, and infests several crops including

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those of vegetables, cereals, legumes, fodders, pulses, oilseeds, fiber crops, fruit plantations, lawns and non-agricultural settings (Holm *et al.* 1977). The weed takes place among the noxious and most difficult to control weeds. Allelopathic potential of the weed against crops has also been reported previously (Quayyum *et al*. 2000).

Mulching the soil with some degradable (organic) or non-degradable (inorganic) materials has been used to accomplish benefits such as conservation of moisture, reduction in soil erosion, increase in microbial activities in the soil and pest control (Dong *et al*. 2008; Kasirajan and Ngouajio 2012; Haapala *et al*. 2014; Jabran and Chauhan 2018). Plastic (particularly black colored one) has been intensively used for several of its benefits in agricultural systems (Scarascia-Mugnozza *et al*. 2011; Jabran *et al.* 2015b). Recently, there has been an increase in the investigations that focus on exploring the role of plastic mulches in different types of agricultural systems (Thankamani *et al*. 2016). However, there are questions regarding the ecological sustainability and environmental impacts of plastic mulching (Kader *et al*. 2017). Degradable alternatives of plastic mulching are also available that not only provide several ecological benefits but are also effective in control of weeds (and other pests) and do not leave ill impacts on soil health and the environment (Haapala *et al*. 2014; Dietrich *et al*. 2019; Wang *et al*. 2019). Straw mulch, craft paper mulch, card-board and woodchip are a few important ones among these alternatives. These degradable mulches are also named as organic mulches against the non-degradable (plastic) or inorganic mulches. Mulches can suppress or kill the weeds through several mechanisms such as physical suppression, obstruction of light, reduced air circulation and an allelopathic impact.

Spinach is a cool-season leafy vegetable that is rich in minerals and nutrients, and is consumed in almost all parts of the world. Weed infestation is an important plant protection problem in spinach production (Wallace *et al.* 2007). Market value of spinach is greatly reduced if some weed plants are mixed with spinach plants. There are very few herbicide options for weed control in spinach and the available options are also likely to cause injury to spinach plants and leave a herbicide residue in the leafy (consumable) parts (Fennimore *et al*. 2001; Fennimore and Doohan 2008; Fan *et al*. 2013). Hence, non-chemical weed control measures are desired for production of healthy spinach. Use of mulches may be the most attractive option because mechanical control is supposed to damage the delicate spinach plants.

This research work was aimed to evaluate the effect of different organic (degradable) and inorganic (non-degradable) mulches for non-chemical control of field bindweed and purple nutsedge. The objective was to study the effect of different mulches on the suppression, plant height, and biomass of the weeds. The second study was aimed to evaluate a non-degradable (thin-plastic) and two degradable (craft paper and wheat straw) mulches for weed control in spinach. The effect of these mulches on the weed and crop cover in spinach plantation was tested.

Materials and Methods

Study 1 (field experiment)

The experiments were conducted in the Faculty of Agriculture and Natural Sciences, Duzce University, Duzce, Turkey during 2018. The experiment was conducted during spring and repeated in the summer season. Soil properties of the experimental area have been presented in Table 1.

Area was selected that was infested with weeds including field bindweed and purple nutsedge. Both the weeds were allowed to grow until these were at their peak vegetative growth stage. Parts of the field that were heavily infested with these weeds were applied with the mulches including: weedy (no mulch), thick (0.25 mm) and thin (0.05 mm) black plastic mulches, craft paper (brown colored) mulch (0.23 mm), thick cardboard (2.83 mm) mulch, woodchip mulch (2.67 mm) and wheat straw mulch at 5 t ha^{-1}. The experiment was laid out according to randomized complete block design, and each treatment had three replications and an area of 1 m × 1 m. The fields were kept covered with the mulches for a period of 18 days each for the spring and summer experiment.

The physical condition of each mulch was noted at termination of the studies. Towards end of the studies, the mulches were removed carefully to record data on weed control (%) provided by each mulch. The condition of the weeds (because of implementation of the treatments) were observed keenly and compared with the control (no mulch) to visually assess the percent weed control. A scale of 0 to 100% was used to record percent weed control; 100 was considered as full weed control and 0 was considered as no weed control. Moreover, data on weed height was recorded with help of a measuring meter. Weed height was recorded from five plants in a plot at termination of the study with help of a measuring meter starting from base of the plants up to their tips. Weeds (only the aboveground parts) were harvested with the help of scissor and immediately weighed to determine the fresh weight. These were then dried (until constant weight) in an oven at 70°C to determine the dry weight.

Study 2 (pot study)

Mulches were evaluated for controlling weeds in a leafy vegetable *i.e*., spinach. The treatments included: (i) thin (0.05 mm) black plastic mulch, (ii) craft paper (brown colored) mulch (0.23 mm), (iii) wheat straw mulch (5 t ha^{-1}), (iv) weed-free, and (v) control (weedy-check). Seeds of spinach cultivar Matador were sown in pots having a size of 1 m × 0.3 m, and filled with a mixture of sand, compost and perlite (2:1:1). Sowing was done in the first week of

October 2018 using a seed rate of 25 kg ha^{-1}, and seeds were sown at a soil depth of 2 cm. Mulches were placed in the pots manually and the spinach intra-rows were kept free of the mulches. The experiment was conducted according to randomized complete block design with three replications. The analysis for soil used in the experiment has been given in the Table 1.

Spinach plants were allowed to grow for a period of two months. Afterwards, visual observations were made to record percent cover (for whole of the planted areas) attained either by weeds or the crops, and the percent weed control. Percent weed control assessment was based on a scale of 0 to 100% where 0 meant no control was achieved and 100 meant a complete control of the weeds.

Statistical analysis

Recorded data were tested for variance homogeneity and normal distribution. Data were subjected to analysis of variance using STATISTIX 8 Analytical Software to determine significance of the treatments. 'Season' (summer and spring) and the mulch treatments were considered as factors, results of both the summer and spring experiments did not differ significantly, hence, the data were pooled for a subsequent analysis and presentation. The differences among the treatment means were determined according to Tukey's HSD test at 0.05 alpha level.

Results

Study 1 (field experiment)

Both the plastic mulches and woodchip mulch did not witness damage during the experimental period; however, other mulches had minor deformations (Table 2). Both the card-board and craft paper mulches absorbed water and were deformed by 50–60% approximately. Wheat straw mulch was originally yellow in color and its color started changing to brown and black.

Mulches had significantly affected the percent control, weed height, seedling fresh weight, and seedling dry weight of the field bindweed (Table 3). Thick and thin black plastic mulches, card-board, craft-paper, and wood-chip mulches provided the highest and statistically similar inhibition of field bindweed followed by the wheat straw mulch (Table 3 and Fig. 1). The greatest field bindweed height was noted for plants in control treatment while all the mulches caused a significant and statistically similar decrease in height of field bindweed. Similarly, the control plots possessed the highest seedling fresh weight and dry biomass of field bindweed and all the mulches caused a significant and statistically similar reduction in seedling fresh weight and dry biomass. Both the organic and inorganic mulches caused a similar reduction in the weed height, fresh weight and dry weight of field bindweed. The visible condition of field bindweed plants in response to application of organic and inorganic mulches is presented in Fig. 1.

Organic and inorganic mulches caused a significant decrease in purple nutsedge infestation (Table 4). Thick black plastic mulch gave the highest control of purple nutsedge followed by thin black plastic mulch and card-board mulch. Among the mulches, wheat straw mulch was least effective in suppressing purple nutsedge. The greatest weed height, seedling fresh weight and dry biomass of purple nutsedge were noted in the weedy-check (control). Moreover, all the mulches (degradable and non-degradable) caused a statistically similar decrease in weed height, seedling fresh weight and dry biomass of purple nutsedge. Fig. 2 shows condition of purple nutsedge plants as affected by different mulches in the study.

Study 2 (pot experiment)

Wild oat (*Avena fatua* L.), shepherd's purse (*Capsella bursa-pastoris* (L.) Medik.), and perennial ryegrass (*Lolium perenne* L.) were the three weeds found in weedy-check and other weed control treatments. The approximate densities of these weeds were 40% for wild oat, 35% for perennial ryegrass and 25% for shepherd's purse. The mulches had significantly and variably affected the weed cover, crop cover, and weed control in spinach (Table 5). The highest weed cover (%) was noted in control (weedy-check) followed by wheat straw mulch. The lowest weed cover was noted for the spinach grown in the weed-free environment followed by the thin black plastic mulch and craft-paper mulch. The lowest crop cover was noted for the weedy-check. Thin black plastic mulch provided the highest weed suppression followed by the craft-paper mulch while wheat straw mulch provided the lowest suppression of weeds in spinach (Table 5).

Discussion

This study was aimed at evaluating inorganic and organic mulches for controlling field bindweed and purple nutsedge, and non-chemical weed control in spinach vegetable. None of the mulches witnessed a significant damage and were in good condition by the end of the experiment; however, minor deformations were noted on the degradable mulches. Generally, plastic mulches are known to suppress the weeds for one to two growing-seasons (nearly one year) (Ham *et al*. 1993; Ngouajio and Ernest 2005). However, they may have weakened physical, optical and thermal properties after a single season and may not provide benefits in addition to weed control and soil moisture conservation (Ham *et al*. 1993; Ngouajio and Ernest, 2005). The plastic mulches with weakened thermal and optical properties cannot properly accomplish the modification of the microclimate or heating of the soil surface (Ngouajio and Ernest 2005). In this study, the condition of mulches could be monitored only for 20 days because visual assessments indicated that weeds were effectively withered and controlled during this duration. Fading and initiation of deformation in the organic mulches

Table 1: Soil properties of the experimental site for the study 1 and study 2

Soil characteristics	Study 1	Study 2
Soil texture	Loamy sand	Clay loam
pH	7.44	6.79
Organic matter (%)	3.00	4.77
Nitrogen (%)	0.15	0.24
Available phosphorus (mg kg^{-1})	69.20	82.2
Extractable potassium (mg kg^{-1})	81.80	91.6
Extractable iron (mg kg^{-1})	3.30	3.96
Extractable zinc (mg kg^{-1})	0.36	4.36

Table 2: Physical (visible) condition of mulches at the end of experimentation

Mulch type	Condition at the end of experiment
Thick black plastic mulch	No change in the condition
Thin black plastic mulch	No change in the condition
Card-board mulch	Absorbed moisture; 50% deformation
Craft paper mulch	Absorbed moisture; approx. 60% deformation
Wheat straw mulch	Straw started deforming and turned blackish
Woodchip mulch	No change in the condition

Table 3: Effect of various inorganic and organic mulches on control and growth of field bindweed

Mulch type	Weed control (%)	Plant height (cm)	Seedling fresh weight (g)	Seedling dry weight (g)
Control (weedy-check)	0.0 c	61.0 a	48.0 a	10.9 a
Thick black plastic mulch	99.2 a	33.6 b	3.6 b	1.3 b
Thin black plastic mulch	99.0 a	38.1 b	4.2 b	2.0 b
Card-board mulch	96.2 a	38.7 b	5.3 b	2.2 b
Craft paper mulch	94.2 a	42.4 b	4.9 b	1.6 b
Wheat straw mulch	76.2 b	42.1 b	10.3 b	3.3 b
Woodchip mulch	95.3 a	39.6 b	5.1 b	3.0 b

The data is an average of two-season experimentation; the means not sharing a letter in common differ significantly at $P \leq 0.05$ according to Tukey's HSD test

Table 4: Effect of various inorganic and organic mulches on control and growth of purple nutsedge

Mulch type	Weed control (%)	Plant height (cm)	Seedling fresh weight (g)	Seedling dry weight (g)
Control (weedy-check)	0.0 e	58.8 a	34.9 a	8.8 a
Thick black plastic mulch	100.0 a	37.4 b	2.7 b	2.3 b
Thin black plastic mulch	98.0 ab	37.0 b	2.4 b	2.0 b
Card-board mulch	96.7 abc	39.8 b	3.3 b	1.4 b
Craft paper mulch	91.7 c	35.2 b	1.9 b	0.8 b
Wheat straw mulch	57.8 d	43.4 b	8.0 b	2.0 b
Woodchip mulch	93.3 bc	33.7 b	1.7 b	0.5 b

The data is an average of two-season experimentation; the means not sharing a letter in common differ significantly at $P \leq 0.05$ according to Tukey's HSD test

Table 5: Effect of various inorganic and organic mulches on weeds and crop cover in spinach

Mulch type	Weed cover (%)	Crop cover (%)	Weed control (%)
Control (weed-free)	0.0 d	65.0 a	100 a
Control (weedy-check)	86.7 a	30.0 c	0.0 d
Thin black plastic mulch	8.0 cd	55.0 ab	90.0 ab
Craft paper mulch	20.7 c	49.0 ab	83.0 b
Wheat straw mulch	40.7 b	39.3 bc	49.0 c

The means not sharing a letter in common differ significantly at $P \leq 0.05$ according to Tukey's HSD test
Percent weed control assessment was based on a scale of 0 to 100% where 0 meant no control achieved and 100 meant a complete control of the weeds

(wheat straw, card-board and craft paper) were positive signs in the environmental protection perspective (Valenzuela-Solano and Crohn 2006; Halde and Entz 2016). This implies that a clean and mulch-residue free environment will be witnessed after the decaying and decomposition of the organic mulches during the subsequent cropping seasons. Environmental benefits of organic mulches over the inorganic mulches are well established and reported (Jabran 2019).

All the mulches provided a significant control of the weed species in the first study (*i.e.*, field bindweed and purple nutsedge) and the second study *i.e.*, weeds in the spinach (wild oat, shepherd's purse, and perennial ryegrass). The two plastic mulches (thick and thin) were equally effective in suppressing the two weeds and causing a decrease in their height, fresh weight and biomass. Probably a single season application is not enough to express the difference in efficacy of thick and thin plastic mulches

Fig. 1: Effect of different organic and inorganic mulches on field bindweed: (**a**) control (no mulch), (**b**) thick black plastic mulch, (**c**) thin black plastic mulch, (**d**) craft-paper mulch, (**e**) card-board mulch, and (**f**) wheat straw mulch

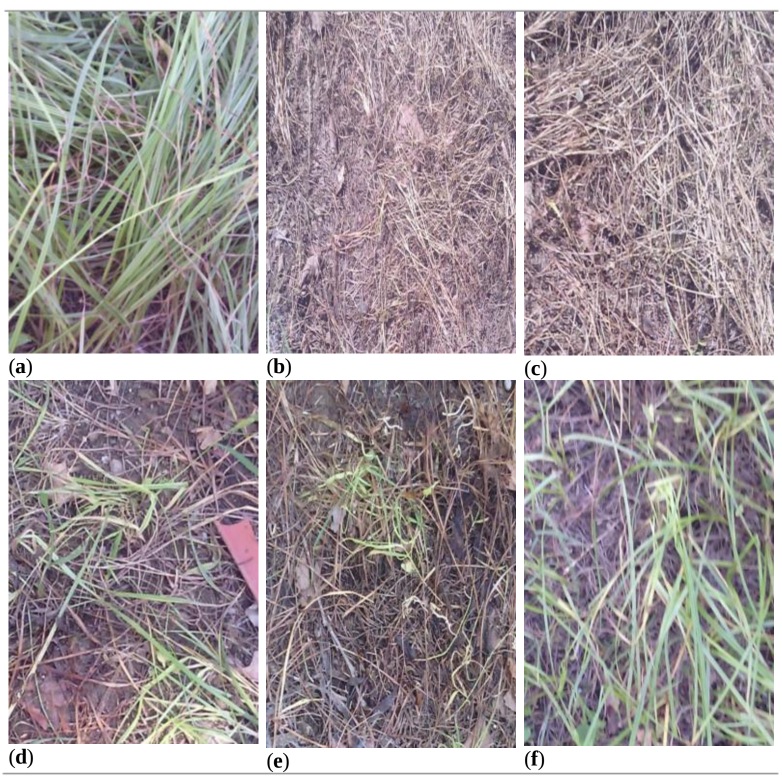

Fig. 2: Effect of different organic and inorganic mulches on purple nutsedge: (**a**) control (weedy-check, no mulch), (**b**) thick black plastic mulch, (**c**) thin black plastic mulch, (**d**) craft-paper mulch, (**e**) card-board mulch, and (**f**) wheat straw mulch

(Changrong *et al*. 2014). Organic mulches (woodchip, cardboard, craft paper) were effective in suppressing the two weeds but were not different from inorganic mulches in their efficacy. Nevertheless, percent weed control of field bindweed and purple nutsedge through wheat straw mulch was lower than the other mulches, however, all the mulches had a similar effect on rest of the weed traits. Nevertheless, field bindweed and purple nutsedge take place among the most problematic weeds in the agricultural crops and in non-agricultural settings as well, and very few control options are available to suppress these weeds effectively (Baumgartner *et al*. 2007; Orloff *et al*. 2018).

The effectiveness of mulches against these weeds in this study implies that they can be tested and used for weed control in areas heavily infested with these weeds. Presumably, the mulches in the study exercised a variety of mechanisms to suppress the studied weed species. Previously, this has been reported that weed suppression through mulches is accomplished through a variety of mechanisms (Jabran 2019). Importantly, the weed suppression mechanism varies depending on the nature of mulch. Apparently, the plastic mulches (both the thin and thick) in this study suppressed the weeds (field bindweed and purple nutsedge, and the weeds growing in spinach plants) by blocking the sunlight and exerting a physical pressure as well on the weeds (Jabran 2019).

The mechanisms of weed suppression by card-board and craft paper mulches are similar to that of plastic mulches (*e.g*., blocking of light, physical pressure *etc*.). Another likely mechanism of weed suppression by mulches is the obstruction of air circulation to the weeds, and this ultimately created an anoxic or at least a hypoxic environment for the weed plants (Zhang *et al*. 2015). Plastic mulches possess a great capability to create anoxic or hypoxic environment than the other mulches. Another possible mechanism of weed suppression by mulches is the heating of soil environment and a subsequent damage to the weed tissues. Mulches are known to decrease the albedo of the soil (Zhang *et al*. 2015). Nevertheless, this has also been reported that inorganic mulches reduce the water availability to weeds (Saha *et al*. 2018).

Although lower than the other mulches, straw mulch (as observed in this study) also provided a satisfactory suppression of weeds. Straw mulch share several of weed suppression mechanisms (such as physical stress, obstruction of light and moisture supply to weeds and heating of soil) with the plastic, craft paper or card-board mulches. The additional mechanism of weed suppression by the mulches of plant origin include the release of allelochemicals that can express and allelopathic activity against the weeds (Jabran *et al*. 2015a; Saha *et al*. 2018). The straw mulch used in this study was obtained from the wheat, and this crop possesses a proven allelopathic activity (Wu *et al*. 2001; Jabran and Farooq 2013; Jabran *et al*. 2015a).

Importantly, a careful use of mulches is desired owing to certain of their damages to environment, the crop plants or other living organisms in the environment. Further, another important consideration includes the comparative costs expended on different mulch types and the subsequently achieved weed control (or other additional benefits or damages). In addition to the field or horticultural crops, the mulches are likely to provide several benefits in landscape plantations including that of a non-chemical weed control (Chalker-Scott 2007; Saha *et al*. 2018). Non-chemical weed control in landscape can ensure an herbicide free and healthy environment for the people coming in contact with that environment (Marble *et al*. 2015). Chalker-Scott (2007) described a number of benefits of mulching to landscape such as improved aesthetics, control of weeds, reduction in disease infestation, improved germination (of landscape plants), enhanced plant growth and establishment, and betterment in the soil hydrothermal, nutritional and microbial status.

Conclusion

Both the organic and inorganic mulches were effective in suppressing the two hardy weeds *i.e*., field bindweed and purple nutsedge, and helped in achieving clean fields of spinach. The lowest weed control efficacy was noted for the wheat straw mulch. Results of these studies have important implications in the perspective of safe food production and environmental protection. Importantly, the significance of non-chemical weed control methods has increased over the time due to quest for organic food production and evolution of herbicide resistance in weeds.

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