Johnson Grass (*Sorghum halepense*) Interference, its Effect on Crops Yield and Soil Biogeochemistry under Different Cropping Systems and Management Practices

ABSTRACT

Johnson grass (*Sorghum halepense)* is one of the most detrimental and toxic weeds among the weed species. Its environment is expanding unceasingly due to deeply expanding of its rhizomes in the soil, self-pollinating reproduction strategy, accelerated growth and poor management which results in production losses of major agronomic crops. Mungbean and sorghum are important crops grown on significant acreage around the world, and a major constraint for their production losses is weeds interference. Thus, field studies were conducted to examine Johnson grass interference, control, and recovery under different management practices and cropping system and its effects on crops production and soil health. Our results indicated that the Johnson grass density was minimized by the application of plastic sheet mulch (PSM) treatment (PSM) under CS_2 (wheat-mungbean). Johnson grass competition had a significant impact on growth and grain yield of bothmungbean and sorghum. The crop yield parameters; 100 grain weight and grain yield were lowest in the non-treated treatment (C), while the greatest values of these parameters were recorded in the plastic sheet mulch (PSM) and wheat straw mulch (WSM) treatments with CS_2 (wheat-mungbean). Similarly, soil building attributes; available nitrogen, available phosphorus, available potassium and organic matter content were positively affected by the interactionof plastic sheet mulch + CS_2 (wheat-mungbean). Biomass of soil bacterial community has increased significantly with the interactive effect of wheat straw mulch + CS_2 (wheat-mungbean). Overall, we have concluded that CS_2 (wheat-mungbean) and CS_1 (wheat-sorghum)are most resilient cropping system with the implementation of plastic sheet mulch (PSM) and wheat straw mulch (WSM) to suppress the spread of Johnson grass.

Keywords: Johnson grass, crop yield, soil health, cropping systems, legumes, cereals

INTRODUCTION

Johnson grass (*Sorghum halepense*) is the world's most precarious and persistent weed that is C4 perennial graminoid plant species from the Poaceae family (Holm *et al*. 1997). Agricultural land and natural biodiversity have been severely deprived by the spread of Johnson grass across all over the globe; Asia, Africa, America, and Europe, covering a one third of the world's field area (Chirita *et al*. 2007). It is rankedsixthamong the worst weedsin whole world that has infested 30 different crops in 53 countries and invading millions of hectares (Valverde & Gressel 2006). It was introduced as a perennial fodder crop, but its invasive and tenacious nature has made it a nuisance to agricultural productivity (Hoffman & Buhler2002; Binimelis*et al*. 2009). Because of its high core competencies and allelopathic potential, *Sorghum halepense* is eminent for having a detrimental impact on neighboring plant growth and development (Novak *et al*. 2009; Huang *et al*. 2015). In cultivated regions, it has resulted in significant yield losses in economically important crops such as wheat, soybean, maize, cotton, vegetables, and fruits (Mitskas*et al*. 2003; Uludag*et al*. 2007; Uremis*et al*. 2009). When the cyanide content of weed is high, grazing on *S. halepense* causes harm to cattle, sheep, and horses during winter (Henderson, 2001). Because of its multiple ways of propagation, fast-growing behavior and resilience to extreme climatic fluctuations, *S. halepense* may thrive in a range of locations and ecological niches (Mihovsky&Pachev 2012; Vila-Aiub*et al*. 2013). These biological characteristics of *S. halepense* have contributed to its reputation as a difficult-to-control weed, as well as impacting the effectiveness of intercultural operations to control *S. halepense* in diverse crops (Dalley & Richard 2008; Heap 2014).

Cropping systems are described as thepattern of crops that are grown throughout the large area, as well as the methods used to cultivate crops (Blanco-Canqui & Lal, 2010). The sequence of crops that are grown on larger areas to get maximum benefits are referring to cropping system and for successful completion of crop production is improved by management practices. Different managerial measures, including as tillage, crop residue management, cropping sequence, nutrients, irrigation, and erosion control, are necessary for the effective and efficient development of crops in a given cropping system (Blanco-Canqui & Lal, 2010). The agricultural system management has a positive influence on soil and water conservation. Soil fertility is improved, soil erosion is reduced, and soil properties are improved with a well-balanced farming approach. Cropping methods with poor management, on the other hand, lead to decreased soil fertility and increased erosion. Monocropping has a number of negative implications, including poor soil qualities, increased fertilizer and pesticide usage, weed and insect infestations, and decreased crop yields (Blanco-Canqui & Lal, 2010).

Mulches have been used for vegetable cultivation since ancient times, and it got its origin from word ‘molsch’, a German word which has meaning "easy to decay" (Lightfoot 1994). This practice of covering soil to intercept the germination of weeds and loss of moisture which optimizes crop production by spreading of different covering material is termed as mulches (Nalayini 2007; Kader *et al*. 2019). They not only improve the yield production but also nourish the soil, ameliorate the soil penetration, diminish the runoff, reduce the rate of evapotranspiration and restrict the weeds emergence to large extent (Rathore *et al*. 1998). They have variety of important environmental benefits including soil and plant root temperature regulation, decreased nutrient losses, reduced soil erosion and compaction, and improved physical soil conditions (Ngouajio&McGiffen 2004; Lamont 2005).

Mulching works as a barrier to light penetration under the surface, preventing weeds from completing photosynthetic activities. The efficient way of getting rid of annual weeds is to use the mulch (Ahmad *et al* 2015; Ahmad *et al* 2020). The emergence and growth of weeds is inhibited by use of mulches and other cultural practices that have been used to overcome weeds are minimized due to their effectiveness. The most effectual mulch that is applied to control the spread of weeds in cotton is plastic sheet. The weed density can be significantly decreased by cumulativequantity of mulch (Ahmad *et al* 2015; Ahmad *et al* 2020)

MATERIALS AND METHODS

Experimental Location and Treatments

The experiment was conducted in field on University Research Farm, Koont, PMAS Arid Agriculture University, Rawalpindi in growing year 2021–2022. The climate of URF,Koont, Rawalpindi is arid to semi-arid. The metrological data gathered throughout the experiment is depicted in Figure 1.

Three cropping systems (CS) were used in this experiment: wheat-sorghum (CS$_1$), wheat-mungbean (CS$_2$) andwheat-fallow (CS$_3$). Four weed control techniques were factorial paired with the CS: control (C), deep ploughing (DP), wheat straw mulch (WSM), and plastic sheet mulch (PSM). The experiment was set up in a split-plot layout using a randomized complete block design (RCBD). Cropping systems were arranged in main plots while sub plots were consisted of management practices. This experiment had three replications and total plot size was 30 m x 20 m. During the wheat growing season, weeds were physically eradicated upon their emergence while in summer season Johnson grass was controlled by applying different management strategies. In control treatment, nothing was applied which allowed the weed to emerge and grow for the comparison with other treatments while in DP treatment, deep ploughing was done before sowing in all the main plots including fallow where nothing was grown in both years. Wheat straw mulch (WSM) was spread manually on the soil after land preparation and before sowing of the mungbean and sorghum. Plastic sheet mulch (PSM) was applied on soil between lines 15 days after sowing mungbean and sorghum while it was applied immediately after land preparation in fallow plot.

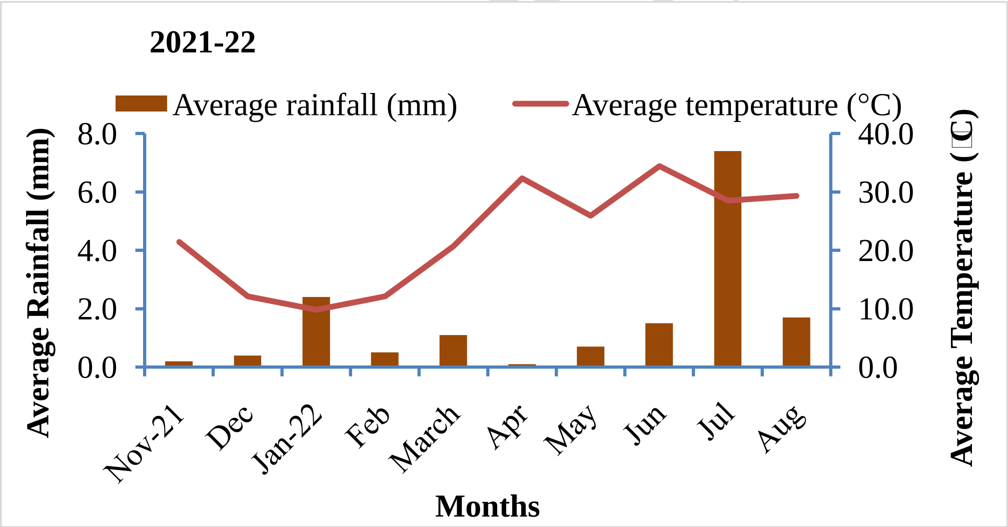

Figure 1. Average temperature and rainfall in the experimental site (University Research Farm, Rawalpindi) in 2021-22. (Source: Climate Observatory at University Research Farm, 350 m away from experimental location)

Crop Husbandry

The experimental area received 10 cm of pre-soaking irrigation during both seasons. For the preparation of seedbed, soil had to achieve field capacity. Table 1 shows the crops that were grown according to the suggested production technology for the area. With a hand drill, all the crops were manually seeded in lines. The irrigation was completely dependent on precipitation.

Urea and di-ammonium phosphate were used as fertilizers (DAP). All the phosphorus was added to soil at time of sowing and 1/3rd portion of nitrogen was applied at sowing time. The rest of the nitrogen was applied during the first and second irrigations, respectively. In cropping season, diseases, insects, and pests were managed by implementing the necessary agronomic and crop protection methods. The grain yield from each plot of each crop was estimated when moisture level was about 12%.

Table 1 Crop husbandry of different crops encompassedin various cropping systems (2021–2022).

Crops	Sowing Time	Varieties	Seed Rate (kg/ha)	Fertilizer NPK (kg/ha)	P-P (cm)	R-R (cm)	Harvesting Time	Harvest Method
Wheat	20 Nov	Barani-2017	125	60-75-0	-	25	09 April	Manual
Mungbean	13 April	NM-2011	75	20–60–0	10	30	08 Sep	Manual
Sorghum	13 April	DS-2003	20	100–60–0	15	60	13 Sep	Manual

P–P = Plant spacing; R–R = Row spacing

Weed Parameters of Johnson grass

Plant density (plants per m^2), plant height (cm), plant fresh weight (g) and plant dry weight (g) were the attributes to determine for Johnson grass. The whole data was calculated from plots ofmungbean, sorghum and fallow. Weed density was calculated from $1m^2$ sample during the booting stage of Johnson grass and plant height was estimated from 10 randomly selected plants. To find out the fresh weights, we had averaged the fresh weights of 10 selected plants for each plot and then dried these samples in oven at 120 Celsius for 24 hours to determine the dry weights with analytical balance.

Agronomic Traits of Mungbean and Sorghum

The agronomic and yield parameters of mungbean and sorghum were taken from each experimental unit. It includes plant height (cm), 100 grain weight (g), straw yield (kg/ha) and grain yield (kg/ha) for mungbean. Similarly, plant height (cm), 100 grain weight (g), straw yield (kg/ha) and grain yield (kg/ha) was the traits for sorghum, Plant height was taken from 10 random plants from each plot. For calculating 100 grain weight, we had averaged the 10 samples from each experimental unit containing 100 grain weight. Straw yield was determined by harvesting plants from area of $1m^2$, dried these samples in oven at 120 Celsius for 24 hours and then weighted. Similarly, plants from $1m^2$ were harvested and then threshed to calculate grain yield of wheat.

Soil Biogeochemistry Analysis

Composite soil samples (0–15 cm depth) were obtained from each experimental unit for postharvest soil analysis of pH. soil organic content (SOM), Available N, P and K. Glass electrode pH meter was used to measure the pH value. To find out the value of soil organic matter content we will multiply organic carbon (OC) by 1.73 while Walkley and Black method was followed to determine OC titrimetrically. Kjeldahl technique was used to calculate available nitrogen. To find the available phosphorus content, soil was agitated with a 0.03 M NH4F—0.025 M HCl solution at a pH of less than 7.0. By employing the ammonium bicarbonate-DTPA method (AB-DTPA), the value of available K was evaluated.

The bacterial biomass was determined by analysis of phospholipid fatty acids (PLFAs) following the protocol of Frostegård et al. (1993). Briefly, PLFAs from two gram (wet weight) soil were extracted in reagent consisting of chloroform, methanol and citrate buffer (1:2:0.8 v/v/v). Phases were separated with chloroform as organic solvent. Lipids were fractionated into neutral lipids, glycolipids and phospholipids using silica acid columns and eluted with chloroform, acetone and methanol, respectively. As an internal standard, methylnondecanoate (19:0) was added to the phospholipid fractions that were then subjected to mild alkaline methanolysis using methanolic KOH. The resulting fatty acid methyl esters (FAMEs) were analysed by gas chromatography and identified by retention time comparison with a standard mixture composed of FAMEs ranging from C4 to C24. The gas chromatograph was equipped with a flame ionisation detector (PE-5 capillary column, 30 m x 0.32 mm i.d.; film thickness 0.25 mm) and as carrier gas helium was used. Measurements started at a temperature of 60°C, increased to 160°C (30°C min21) and then to 260°C (3°C min21).

The PFLAs 18:1w9 and 18:2w6,9 were designated as fungal fatty acids (Frostegård and Bååth 1996, Zelles 1999, Ruess and Chamberlain 2010). 18:1w9 is also present in plant tissue (Ruess and Chamberlain 2010), but as we analyzed soil without plants and fresh plant residues, we assumed this fatty acid to be mainly of bacterial origin. The amount of C in fatty acids (nmol g21 dry weight soil) hereafter is referred to as fungal biomass.

Statistical Analysis

Data from both years were separately subjected to statistical analyses (ANOVA), which was carried out using the Statistix 8.1 statistical package (Shapiro and Wilk, 1965). When the ANOVA model was significant ($p \leq 0.05$), the difference between means was evaluated using a Fisher's LSD test ($p \leq 0.05$) (Steel et al., 1997).

RESULTS AND DISCUSSION

Soil Properties

During both years of the study, different management practices (MP) and cropping systems (CS) had a substantial influence on plant available nitrogen. PSM had the greatest nitrogen value among management methods, whereas C had the lowest. In cropping systems (CS), CS2 had the highest value of plant available nitrogenwhile cropping system CS3 had the lowest value in both growing years.

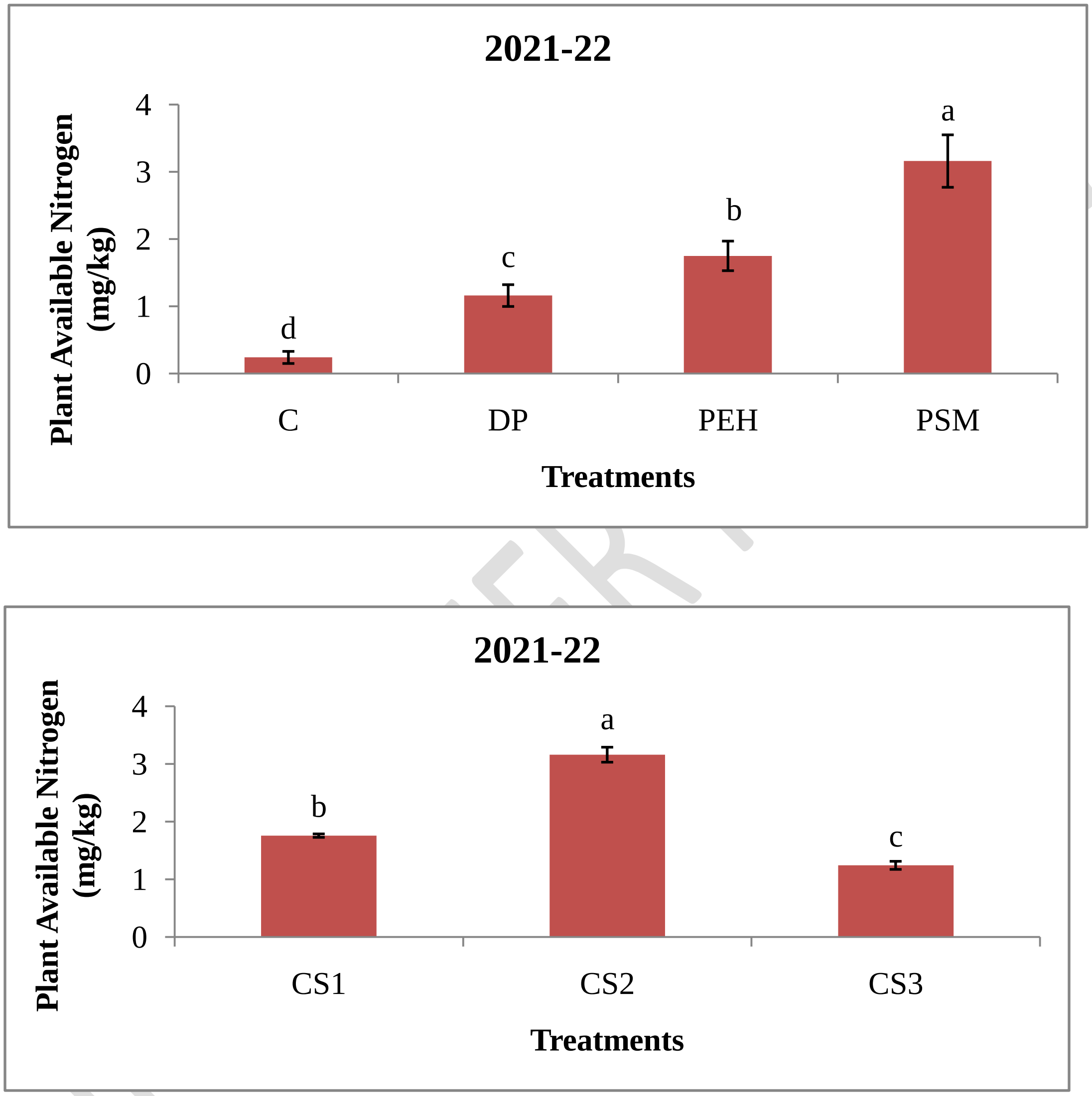

Figure: 2 Effect of numerous management practices (a) and cropping systems (b) on plant available Nitrogen(mg/kg) C = Control, DP = Deep Ploughing, WSM = Wheat straw mulchs, CS1 = Wheat-Sorghum, CS2 = Wheat-Mungbean, CS3= Wheat-Fallow. Any two means sharing different letters are statistically different ($p \leq 0.05$) from each other.

During the two years of the study, MP and CS considerably changed the amount of P that was accessible by the plant in soil. Among the various management practices included in the study, it varied from 6.90 to 20.46 mg/kg in the years 2020–2021 and 7.63 to 19.40 mg/kg in the years 2021–2022. The PSM and WSM produced the greatest values of plant available P during both years, whereas C has theminimum value of soil available P during both years. Similar to this, among the several CS included in the study, soil available P varied from 6.90 to 20.46 mg/kg and 5.90 to 19.4 mg/kg, respectively, over the years 2020–2021 and 2021–2022. During both years of the research, the minimum and maximum values for plant available P were obtained for C2 and C3 cropping systems, respectively (Figure 3).

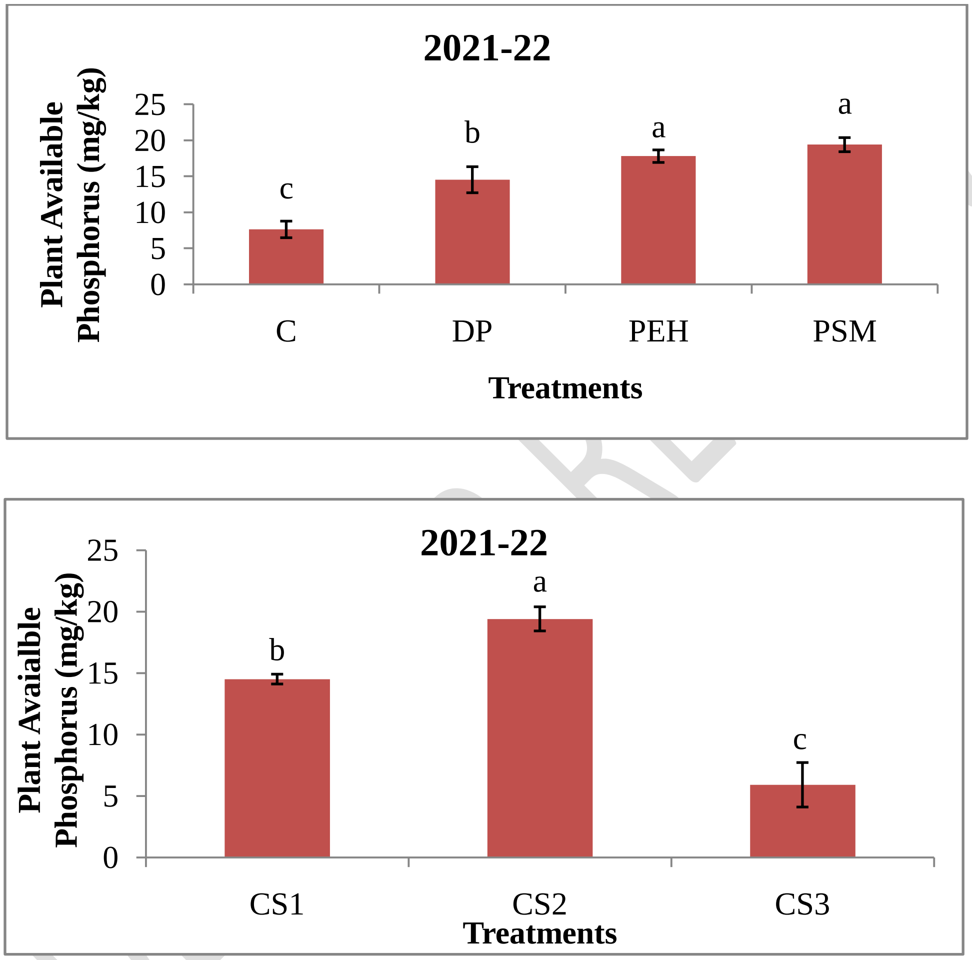

Figure: 3 Effect of numerous management practices (a) and cropping systems (b) on plant available Phosphorus (mg/kg) C = Control, DP = Deep Ploughing, WSM = Wheat straw mulchs, CS1 = Wheat-Sorghum, CS2 = Wheat-Mungbean, CS3= Wheat-Fallow. Any two means sharing different letters are statistically different (p ≤ 0.05) from each other.

During both years of the study, different management practices (MP) and cropping systems (CS) had a substantial influence on plant available potassium. PSM had the greatest soil potassium level among management treatments, whereas C had the lowest. All throughthe years of the study, CS2 had greatest value ofpotassium;however the CS3 cropping system had the lowermost value (Figure 4). Similar to this, throughout the years 2020–2021 and 2021–2022, plant available K ranged among the several CS included in the study from 143.54 to 205.86 and 121.43 to 185.81 mg/kg. The C2 and C3 cropping systems had estimated with maximum and minimum values for plant available K through the time of the experiment, respectively (Figure 4)

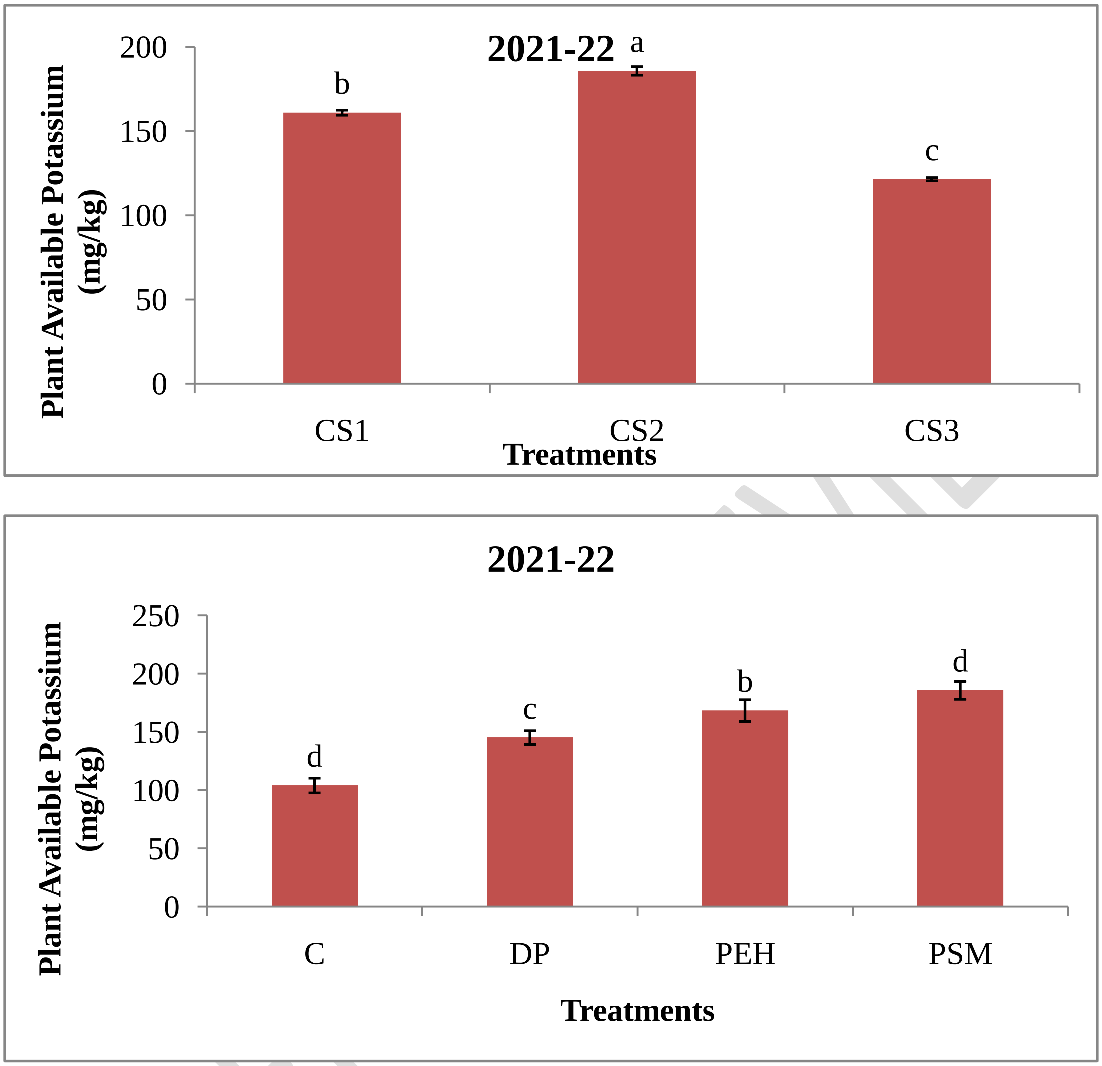

Figure: 4. Effect of numerous management practices (a) and cropping systems (b) on plant available Potassium (mg/kg) C = Control, DP = Deep Ploughing, WSM = Wheat straw mulchs, CS1 = Wheat-Sorghum, CS2 = Wheat-Mungbean, CS3= Wheat-Fallow. Any two means sharing different letters are statistically different ($p \leq 0.05$) from each other.

During the two years of the study, various management techniques (MP) and cropping systems (CS) both had a substantial influence on soil organic matter. In terms of management techniques, PSM recorded the greatest value for soil nitrogen, whereas C recorded the lowest. In both years of the research, the CS2 cropping system had the highest value of soil organic matter, whereas the CS3 cropping system had the lowest value.

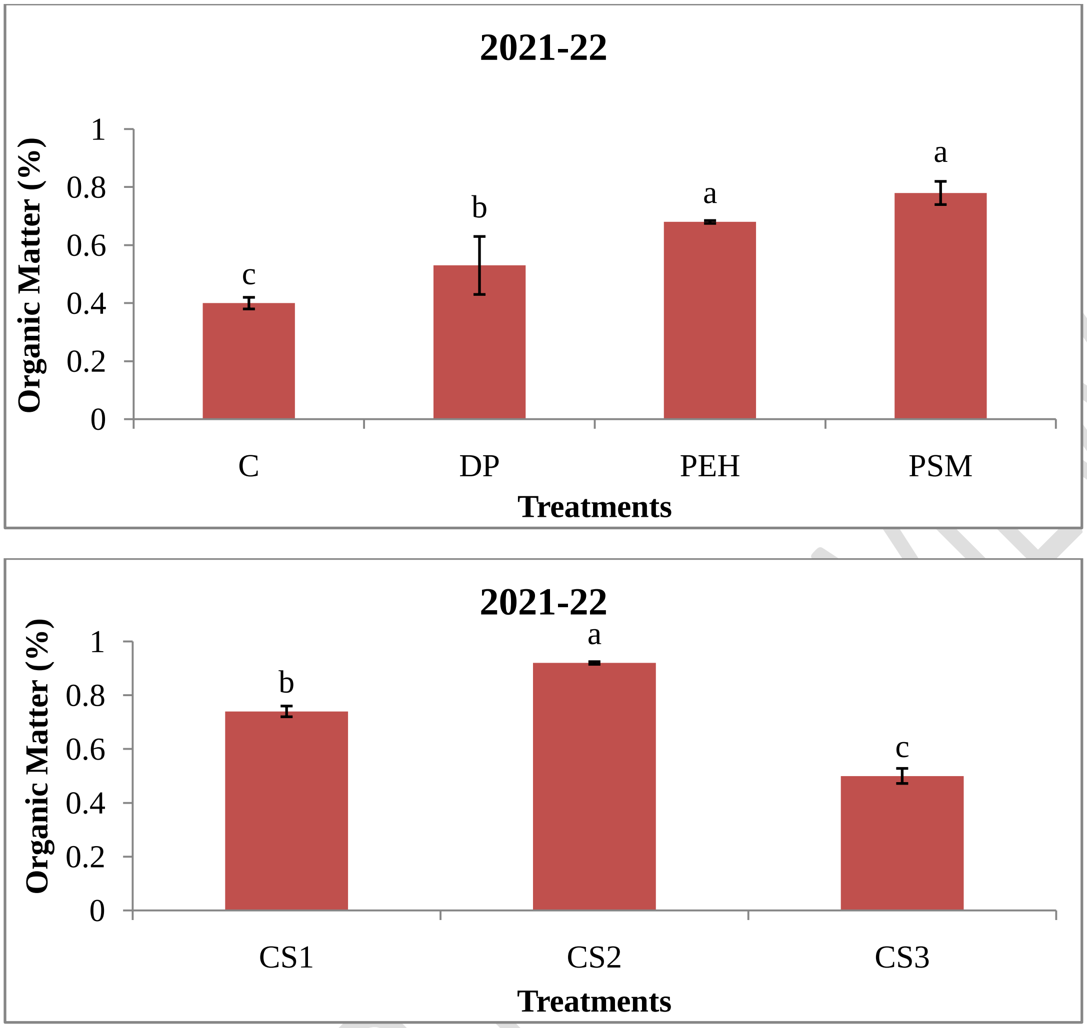

Figure: 5. Influence of various weed control strategies (a) and cropping systems (b) on soil Organic Matter (%). C = Control, DP = Deep Ploughing, WSM = Wheat straw mulch, CS1 = Wheat-Sorghum, CS2 = Wheat-Mungbean, CS3= Wheat-Fallow, the bar indicates the means ± standard errors of the means. Any two means sharing different letters are statistically different ($p \leq 0.05$) from each other.

Weed Parameters of Johnson grass

Plant Density (plants per m^2)

Various management treatments and cropping system had significant effect on plant density of Johnson grass during period 2021 and 2022. However, lowest plant density was recordedin PSM which was followed by WSM while highest plant density was noted in C treatment followed by DP during both growing years (Table 2). Among different cropping systems, maximum number of plants per m^2 was recorded in CS_3 while least possible number of plants in m^2 was experiential in CS_1throughout both growing years (Table 2).

The interactive effect of cropping systems and management treatments in both experimental years drastically influenced plant density of observed Johnson grass. Plant density ranged from 36.70 to 5 plants per m^2 in 2021 and 43 to 7 plants per m^2 in 2022 (Table 2). During both years of the research, all CS had the lowest plant density of Johnson grass with PSM, followed by WSM (Table 2). In both years of the research, all CS had the maximum plant density of Johnson grass with C treatment, whereas CS1 had the lowest (Table 2). CS3 was the most afflicted cropping system overall, however CS1 was slightly affected cropping system amongthe time of experimentation years 2020-21 and 2021-22.

Our outcomes are in proximity with the results of Azadbakht*et al.*, (2017) and Asif *et al.*, (2020) who found that weed density can be reduced by using plastic sheet mulch on soil surface during sowing. Naeem *et al*. (2021) recorded from study that sorghum-based cropping system with different weed management strategies diminished the plant density of Johnson grass. They also found that allelopathic effect of sorghum resulted in minimum. Bachheti *et al.* (2020) also found results related to present study who concluded that growing of allelopathic crops considered best for minimizing the weed density.

Table 2. Effect of different cropping systems and management practices on plant density (plants m^{-2}) of Johnson grass recorded during the periods 2021 and 2022

	2022			
	CS1	**CS2**	**CS3**	**Mean**
C	22.66d	30.33bc	43.00a	**32.00a**
DP	13.67ef	22.00d	32.67b	**22.78b**
WSM	9.33fg	14.00ef	26.67cd	**16.67c**
PSM	7.00g	12.67ef	16.00e	**11.89d**
Mean	**13.16c**	**19.75b**	**29.58a**	

The lowercase letters denote how respective cropping system differed among various management practices. C = Control, DP = Deep Ploughing, WSM = Wheat straw mulch, PSM = Plastic Sheet Mulch, CS$_1$=wheat-sorghum, CS$_2$=wheat-mungbean, CS$_3$= wheat-fallow, CS = cropping-systems and T= management treatments

Plant Height (cm)

The interactive effect of cropping systems and management treatments in both experimental years considerably influenced plant height of observed Johnson grass. During 2021, the plant height varied from 233.06 to 76.91 cm, and 223.76 to 73.17 cm in next year, 2022 (Table 3). During both years of the study, all CS measured the least plant height of Johnson grass using PSM, which was then followed by WSM (Table 3). In both years of the research, all CS recorded the optimal plant height of Johnson grass with C treatment, but the CS1 recorded the minimum value (Table 3). Consequently, CS3 had the highest plant height across all cropping systems, whereas CS1 had the lowest plant height throughout all cropping systems over both years of the experiment.

Our results are in agreement with those of Awal *et al.*, (2016). They found that growth of Johnson grass and other seasonal weeds can be abridged by using plastic sheet mulch in field during sowing of crops. However, David & Chandler, (1987) reported that good to excellent control of Johnson grass was observed for applying herbicide at 8 cm and 16 cm tall Johnson grass**.**

Shahzad *et al*, (2021) recorded that plant height of major weeds like Johnson grass Aramanthus spp. and Partuala spp. has been suppressed when emerged in sorghum fields. Farooq *et al.* (2020) showed that phenolic compounds present in sorghum played pivot role in suppression of plant height of these noxious weeds.

Table 3. Effect of different cropping systems and management practices on plant height (cm) of Johnson grass recorded during the periods 2021 and 2022

	2022			
	CS1	**CS2**	**CS3**	**Mean**
C	194.42bc	217.64ab	223.74a	**211.93a**
DP	167.15d	185.08cd	200.06abc	**184.10b**
WSM	96.62fg	139.15e	168.91d	**134.9c**
PSM	74.60g	105.13f	73.17g	**84.30d**
Mean	**133.20b**	**161.75a**	**166.47a**	

The lowercase letters denote how respective cropping system differed among various management practices. C = Control, DP = Deep Ploughing, WSM = Wheat straw mulch, PSM = Plastic Sheet Mulch, CS$_1$=wheat-sorghum, CS$_2$=wheat-mungbean, CS$_3$= wheat-fallow, CS = cropping-systems and T= management treatments

Plant Fresh Weight (kg/ha)

Data regarding plant fresh weight is presented in Table 4. Plant fresh weight was not found statistically different for different CS but found highly significant for different T during period 2021 and 2022.In management treatments (T), minimum plant fresh weight was recorded for PSM while maximum plant fresh weight was recorded for C followed by DP. In cropping systems (CS), lowest plant fresh weight was estimated in CS1 while maximum fresh weight was observed in CS$_3$ which was statistically similar to CS$_2$ (Table 4).

The interactive effect of cropping systems (CS) and management treatments (T) in both experimental years profoundly influenced plant fresh weight of observed Johnson grass. The fresh weight of the plant varied from 454.85 to 132.5 g in 2021 and 441.73 to 132.44 g in 2022 (Table 4). During both years of the study, all CS measured the minimum plant height of Johnson grass using PSM, which was then followed by WSM (Table 4). In both years of the research, all CS recorded the optimal plant height of Johnson grass with C treatment, but the CS1 recorded the lowest values (Table 4). Furthermore, CS3 had the highest plant height among all cropping systems, while CS1 had the lowest plant height across all cropping systems for both years of the research.

These results are in line with the findings of Azad *et al.,* (2015). They found that application of sheet mulch diminishes the fresh weight of Johnson grass and other summer season weeds. While Mistaskas*et al.,* (2003) found that fresh weight of Johnson grass was diminished by the early application herbicides and its fresh weight increased with greater duration of time.

Khaliq *et al*. (2013) reported that BSr (barley-sorghum) cropping system had minimum recorded weeds fresh weight and it might be because of height of sorghum that hinders the growth of weed grown. Similarly, Czarnota *et al.* (2003) found that sorghum excreted allelopathic chemicals like hydrophobic compound (e.g. *sargoleone*), phenolic acids that inhibited the growth of weeds and diminished the fresh and dry weights of plants

Table 4. Effect of different cropping systems and management practices on plant fresh weight (g) of Johnson grass recorded during the periods 2021 and 2022

		2022		
	CS1	**CS2**	**CS3**	**Mean**
C	403.90ab	422.88ab	441.73a	**422.84a**
DP	342.04c	355.54c	389.08bc	**362.22b**
WSM	168.46ef	258.29d	258.00d	**228.25c**
PSM	132.44f	199.29e	194.89e	**175.54d**
Mean	**261.71b**	**309.00a**	**320.92a**	

The lowercase letters denote how respective cropping system differed among various management practices. C = Control, DP = Deep Ploughing, WSM = Wheat straw mulchs, PSM = Plastic Sheet Mulch, CS_1=wheat-sorghum, CS_2=wheat-mungbean, CS_3= wheat-fallow, CS = cropping-systems and T= management treatments

Plant Dry Weight (cm)

Data regarding plant fresh weight is presented in Table 5. Plant dry weight was found statistically different for both different CS and for different T during period 2021 and 2022.In management treatments (T), minimum plant fresh weight was recorded for PSM while maximum plant fresh weight was recorded for (C) followed by deep ploughing (DP). In cropping systems (CS), lowest plant fresh weight was estimated in CS_1 while maximum fresh weight was observed in CS_3 (Table 5).

Plant fresh weight was changed drastically during both study years due to the interaction between cropping systems (CS) and management treatments (T). In the years 2021 and 2022, the plant's fresh weight varied from 96.29 to 9.43 g and 93.49 to 11.53 g, respectively (Table 5). During the two years of the study, PSM was used to record the minimum plant height of Johnson grass, followed by WSM (Table 5). CS1 was reported with lowest value of plant fresh weight in years 2020121 and 2021-22, although all CS recorded the optimal plant height of Johnson grass with C treatment (Table 5).In general, over the two years of the study, CS3 had the highest average plant height across all cropping systems, whereas CS1 had the lowest average plant height across all cropping systems.

Patil *et al*. (2013) recorded that there was significant decrease in dry weight of weeds by the application of plastic sheet mulch as management practices. Adnan *et al*. (2020) also reported similar findings to the present study that although cover crops with combination of sheet mulch can significantly suppress growth by diminishing the dry weight of weed.

Czarnota *et al.* (2003) reported that sorghum excreted allelopathic chemicals like hydrophobic compound (e.g. *sargoleone*), phenolic acids that inhibited the growth of weeds and diminished the dry weight of plant. On the other hand, Ibrahim *et al*. (2013) also reported similar results that allelopathic extract put negative affect on weeds which suppressed the plant dry of weeds.

Table 5. Effect of different cropping systems and management practices on plant dry weight (g) of Johnson grass recorded during the periods 2021 and 2022

	2022			
	CS1	**CS2**	**CS3**	**Mean**
C	67.11c	80.96ab	93.49a	**80.52a**
DP	62.12c	71.45bc	85.19a	**72.92a**
WSM	26.48ef	36.71de	41.10d	**34.76b**
PSM	11.53g	14.89fg	17.55fg	**14.65c**
Mean	**41.81c**	**51.0b**	**59.33a**	

The lowercase letters denote how respective cropping system differed among various management practices. C = Control, DP = Deep Ploughing, WSM = Wheat straw mulchs, PSM = Plastic Sheet Mulch, CS$_1$=wheat-sorghum, CS$_2$=wheat-mungbean, CS$_3$= wheat-fallow, CS = cropping-systems and T= management treatments.

Agronomic Parameters of Mungbean

Plant height (cm)

Data on the subject of plant height of mungbean as prejudiced by management practices is presented in Fig. 6. Analysis of variance (ANOVA) of the datarevealed that management practices significantly affected the plant height of mungbean in both years 2021 and 2022. Plots sown where plastic sheet mulch treatment was applied produced plants with maximum plant heights of 53.18 cm and 58.46 cm during the period 2021 and 2022 respectively while minimum plantheights (33.98 and 37.17 cm) were found in case of control where nothing was applied as management practices.

Yaqub & Shahzad (2009) indicated a gradual increase in plant height of mungbeanwhen applied with plastic sheet due to solarization which results in reduction of attack of pests and emergence of weeds. Islam & Faruq (2009) also recorded the similar results of increased plant height in mungbean by the application of different plastic sheets. Agele *et al*. (2010) also observed that plastic mulches maximize the plant height of crops and Mohtisham*etal*. (2013) revealed that plastic sheet mulch improves the plant height to larger extent in rice crop.

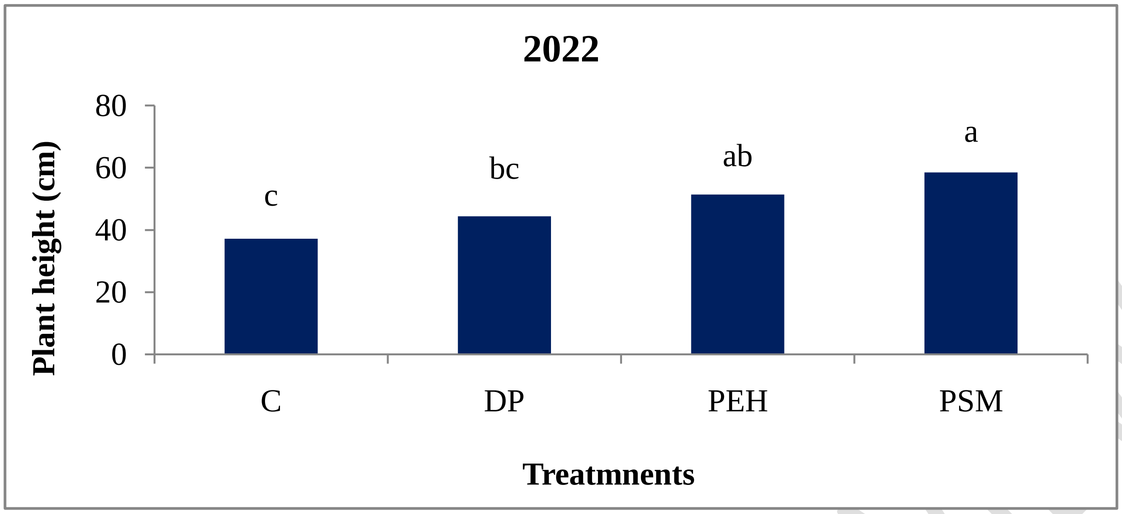

Figure 6: Plant Height (cm) of mungbean as affected by the various management treatments, in 2021 and 2022. C = Control, DP= Deep Ploughing, WSM= Wheat straw mulchs, PSM= Plastic Sheet Mulch. Error bars indicate the LSD5% values.

100 grain weight (g)

In both research years, management techniques considerably changed the 100 grain weight. The varied MP considered in the study varied from 4.89 to 2.75 g in the year 2021 and from 5.02 to 3.26 g in the year 2022. The greatest values of 100 grain weight were obtained from the PSM (4.89 g and 5.02 g) and WSM (4.51 g and 4.08 g) in both years, whilst the lowest values were obtained from the C (2.75 g and 3.26 g) in both years (Figure 7).

The above given results were in line with Mohtisham*et al.* (2013) showing the significant difference among the various treatments in 100 grain weight of crop. 100 grain weight was very much enhanced by using sheet mulch. Similar results were also demonstrated by Xu *et al*. (2007) where mulches improved the 100 grain weight of crop.

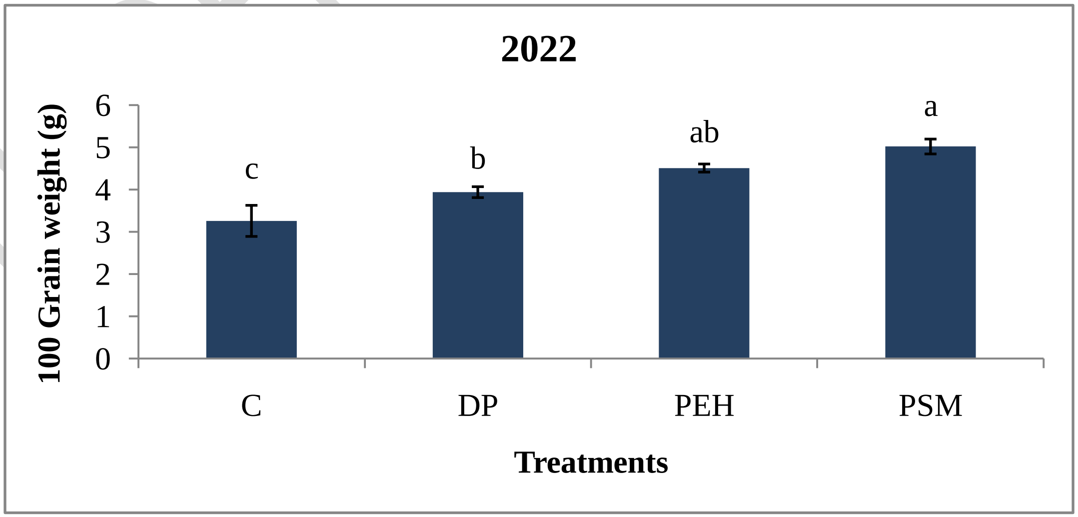

Figure 7: 100 grain weight (g) of mungbean as affected by the various management treatments,

in 2021 and 2022. C = Control, DP= Deep Ploughing, WSM= Wheat straw mulchs, PSM= Plastic Sheet Mulch. Error bars indicate the LSD5% values.

Grain yield (kg/ha)

In both research years, grain yield varied dramatically depending on management strategies. Among the various MP included in the research, it varied between 1154.91 and 761.97 kg/ha during the years 2021 and 1610.7 and 810.27 kg/ha during the years 2022. The maximum grain yield was produced by the PSM (1154.91 g and 1610.7 g) and the WSM (1061.64 and 1150.52 kg/ha), whereas the C (761.97 g and 810.27 kg/ha) produced the lowest average grain yield in both years (Figure 8).

Karim *et al.* (2006) reported that yellow polythene mulch increased the yield and yield contributing characters of tomato by suppressing the TPVV infection and these results were in line with Islam and Faruq (2009) which showed that application of polythene sheet as mulch increased the grain yield of mungbean by 11.73 %. Li *et al*. (2007) showed that plastic film mulch improves the yield in rice and application of polythene sheet as mulch increases the grain yield of rice as the density of weed has been diminished due to increase in temperature of soil (Mohtisham*et al.,* 2013). In sunflower grain yield (24 and 19 t/ha) has been recorded when plastic sheet mulch was applied (Agele *et al*., 2010).

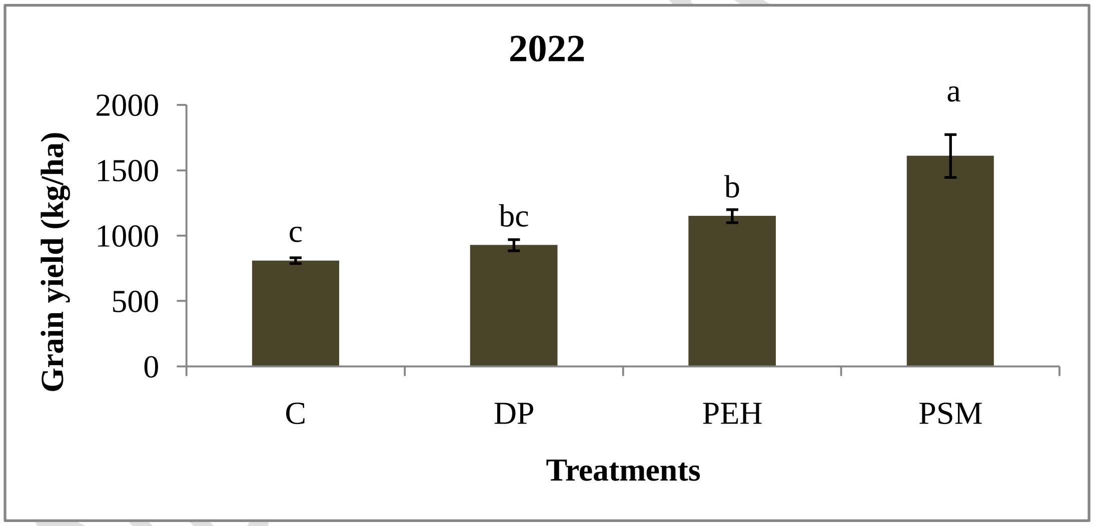

Figure 8: Grain yield (kg/ha) of mungbean as affected by the various management treatments, in 2021 and 2022. C = Control, DP= Deep Ploughing, WSM= Wheat straw mulchs, PSM= Plastic Sheet Mulch. Error bars indicate the LSD5% values

Agronomic Traits of Sorghum

Plant height (cm)

Data regarding plant height of mungbean as influenced by management practices are presented in Fig. 9. Analysis of variance (ANOVA) of the datarevealed that management practices significantly affected the plant height of mungbean in both years 2021 and 2022. Plots sown where WSM treatment was applied produced plants with maximum plant heights of 242.21 and 229.96 cm during the period 2021 and 2022 respectively while minimum plantheights218.61

and 208.46 cm were found in case of control where nothing was applied as management practices.

Similar findings were also reported by Kumar *et al.* (2008) that plant height significantly increased by the application of wheat straw mulch on sorghum. Similarly, Singh *et al*. (2014) also suggested when wheat straw mulch was applied to the crop resulted in the improvement of plant height due to early suppression of pests and weeds and matching results were also found by Khairnar *et al*. (2014) during the application of wheat straw mulchs on crop under observation.

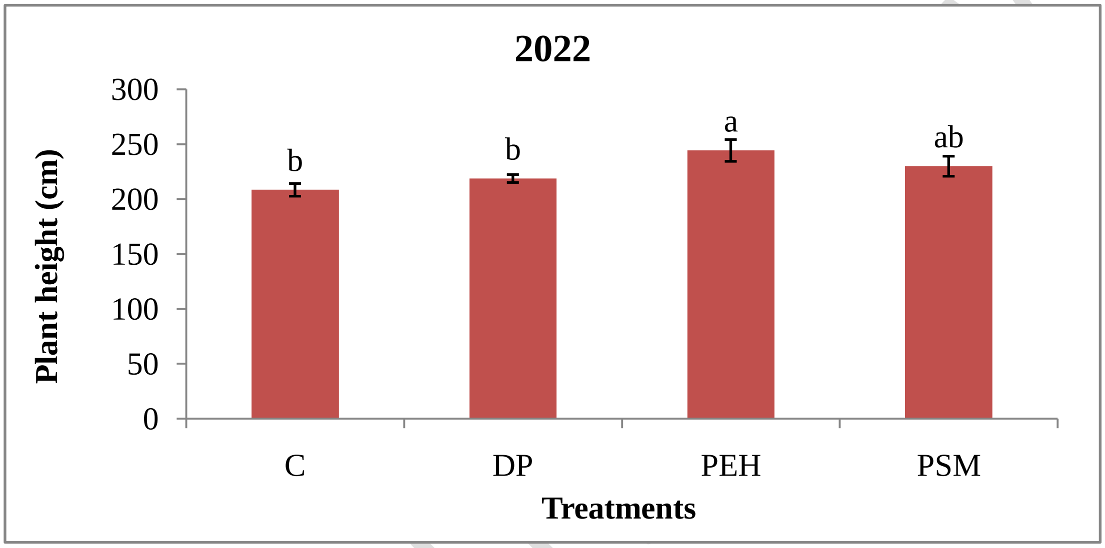

Figure 9: Plant Height (cm) of sorghum as affected by the various management treatments, in 2021 and 2022. C = Control, DP= Deep Ploughing, WSM= Wheat straw mulchs, PSM= Plastic Sheet Mulch. Error bars indicate the LSD5% values.

100 grain weight (g)

Analysis of variance (ANOVA) regarding 100 grain weight showed that management treatments were significant. Maximum no, of grains/pod were 3.46 and 3.81 g recorded in PSM during years 2021 and 2022. It was followed by PSM having 100 grain weight 3.10 and 3.55 g. Furthermore, the 100-grain weight of 2.40 and 2.70 g were found in control (C) during the period 2021 and 2022 (Fig.10)

Burnside & Wicks (1965) had found that application of wheat straw mulchs also put substantial difference on the 100-grain weight of sorghum but El- Samnoudi*et al.* (2009) demonstrating a significant difference in 100 grain weight with the application of mulches during sowing the crop which was according to the results shown in Fig. 10. Additionally, Abdelrahman *et al.* (2016) also found that applying sheet mulch increases the 100-grain weight in almost all crops.

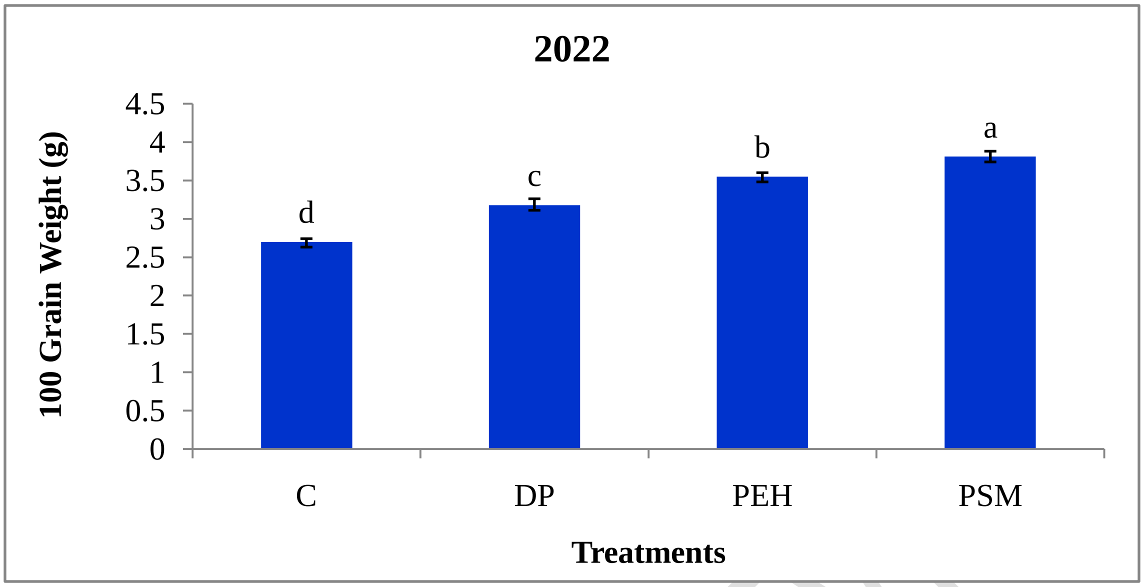

Figure 10: 100 grain weight (g) of sorghum as affected by the various management treatments, in 2021 and 2022. C = Control, DP= Deep Ploughing, WSM= Wheat straw mulchs, PSM= Plastic Sheet Mulch. Error bars indicate the LSD5% values.

Grain yield (kg/ha)

In both research years, grain yield varied dramatically depending on management strategies. Among the various management approaches examined in the research, it varied between 3812.15 and 2214.6 kg/ha between the years 2021 and 2022, and between 4061 and 2555.18 kg/ha during the latter two. The PSM and WSM produced the greatest grain yields in 2021 and 2022, respectively (3812.15 and 4061 kg/ha and 3357.19 and 3595.99 kg/ha, respectively), whereas C (2214.6 and 2555.18 kg/ha produced the lowest grain yields in both years (Figure 11).

Unger & Jones (1981) reported an increase in grain yield and quality of sorghum with the application of sheet mulch as it enhanced the water use efficiency and nutrient uptake.El-Samnoudi*et al.* (2019) also showed that soil mulches increase the grain yield of sorghum to larger degree due to improved soil structure and proper addition of nutrients to soil.

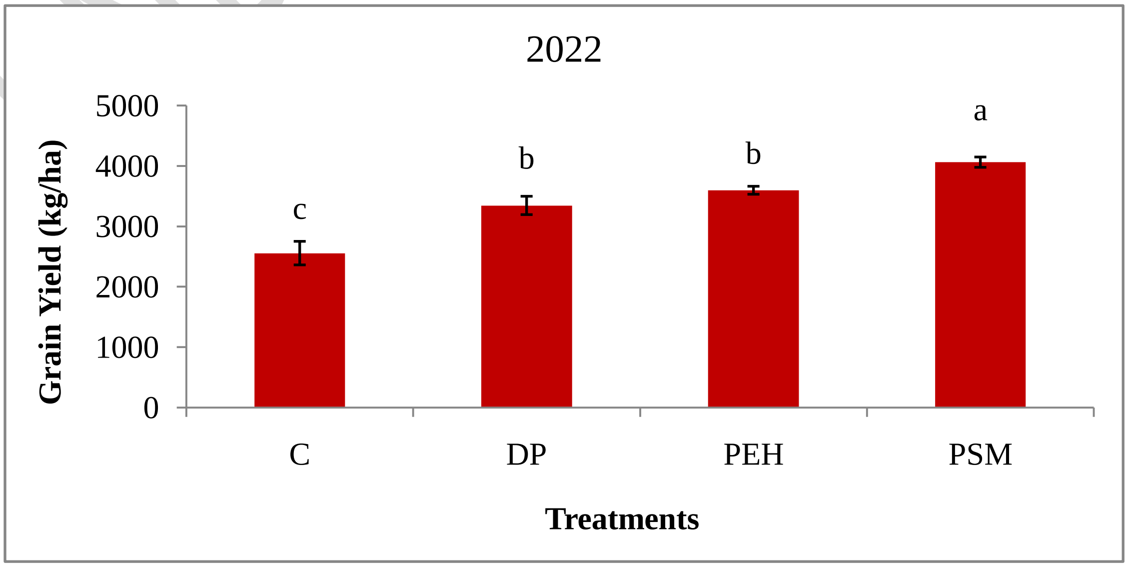

Figure 11: Grain yield (kg/ha) of sorghum as affected by the various management treatments, in 2021 and 2022. C = Control, DP= Deep Ploughing, WSM= Wheat straw mulchs, PSM= Plastic Sheet Mulch. Error bars indicate the LSD5% values.

CONCLUSION

The results of this study indicated that Johnsongrass competition had a strong impact on the growth and yield of mungbean and sorghum. The results showed that application of treatments PSM have suppressed the growth of Johnson grass and increased the yield of mungbean and sorghum. The weed density of Johnson grass in CS_1 was 5 and 7 plants/ m^2 and in CS_2 it was 11 and 12.60 plants/m^2 by the application of PSM during period 2021 and 2022 respectively. It was recorded maximum in non-treated control treatment in all the cropping systems. On the other hand, the average yield for mungbean for treatment PSM was 1154.91 and 1610.70 kg/ha and sorghum yield were 3812.15 and 4061 kg/ha and 3476.60 kg/ha during both study years. The plant density of Johnson grass in CS_1+PSM was 71.14 and 69.10 % was lower than control while it was 60.71 and 58.25 % lower than control in CS_2+PSM. The yield of mungbean was 31.43 and 49.67 % greater than control while sorghum yield was 41.91 and 37.10 %.

REFERENCES

Abdelrahman, N. A., Abdalla, E. A., Ibrahim, E. A., & El Naim, A. M. (2016). The effect of plastic mulch on growth and yield of rain-fed cowpea and watermelon in North Kordofan State of Sudan. *World*, *4*(5), 139-142.

Agele, S. O., Olaore, J. B., & Akinbode, F. A. (2010). Effect of some mulch materials on soil physical properties, growth and yield of sunflower (*Helianthus Annuus*, L). *Advances in Environmental Biology*, 368-376.

Ahmad S, Raza M. A. S, Saleem M. F, Zahra S. S, Khan I. H, Ali M, Shahid A. M, Iqbal R, Zaheer M. S (2015) Mulching strategies for weeds control and water conservation in cotton.,*J. Agric. Biol. Sci* 8:299–306

Ahmad S, Raza M. A. S, Saleem M. F, Zaheer M. S, Iqbal R, Haider I, Aslam M. U, Ali M, &Khan I. H (2020) Significance of partial root zone drying and mulches for water saving and weed suppression in wheat. *J.Anim.Plant.Sci. 30*:154–162

Asif, M., Nadeem, M. A., Aziz, A., Safdar, M. E., Adnan, M., Ali, A., & Abbas, B. (2020). Mulching improves weeds management, soil carbon and productivity of spring planted maize (*Zeamays* L.). *International Journal of Botany Studies*, *5*(2), 57-61.

Awal, M. A., Dhar, P. C. & Sultan, M. S. (2016). Effect of mulching on micro climatic manipulation, weed suppression, and growth and yield of pea (*Pisum sativum* L.). *Journal of Agriculture and Ecology Research International*, 1-12.

Azadbakht, A., Alebrahim, M. T. & Ghavidel, A. (2017). The effect of chemical and non-chemical control methods on weeds in potato (*Solanum tuberosum* L.) cultivation in Ardabil province, Iran. *Applied Ecology and Environmental Research*, *15*(4), 1359-1372.

Azad, B, Hassandokht, M. R. & Parvizi K. (2015): Effect of mulch on some characteristics of potato in Asadabad, Hamedan, Iran. *International Journal of Agronomy and Agricultural Research* 6(3): 139-147

Binimelis R, Pengue W, Monterroso I (2009) ‘‘Transgenic treadmill’’: responses to the emergence and spread of glyphosate-resistant Johnsongrass in Argentina. *Geoforum 40*:623–633

Blanco-Canqui, H.; Lal, R. Cropping Systems. In Principles of Soil Conservation and Management; *Springer*: Dordrecht, The Netherlands, 2010; pp. 165–193.

Burnside, O. C., & Wicks, G. A. (1965). Effect of Herbicides and Cultivation Treatments on Yield Components of Dryland Sorghum in Nebraska 1. *Agronomy Journal*, *57*(1), 21-24

Chauhan, B. S., &Abugho, S. B. (2012). Interaction of rice residue and PRE herbicides on emergence and biomass of four weed species. *Weed Technology*, *26*(4), 627-632.

Chirita R, Grozea I, Sarpe N, Lauer KF (2007) Control of *Sorghum halepense* (L.) species in western part of Romania. *Commun Agric Appl Biol Sci*,73:959–964

Christoffers, M. J., Nandula, V. K., Mengistu, L. W., & Messersmith, C. G. (2004). Altered Herbicide Target Sites. In *Weed biology and management* (pp. 199-210). *Springer*, Dordrecht.

Dalley, C. D., & Richard, E. P. (2008). Control of rhizome johnsongrass (*Sorghum halepense*) in sugarcane with trifloxysulfuron and asulam. *Weed Tech*, 22(3), 397-401.

David, C. B and J. M. Chandler. 1987. Effect of herbicide and weed height on Johnsongrass (*Sorghum halepense* L.) and cotton (*Gossypium hirsutum*) yield. *Weed Tech*. (1): 207-211.

El-Samnoudi, I. M., Ibrahim, A. E. A. M., Abd El Tawwab, A. R., & Abd El-Mageed, T. A. (2019). Combined effect of poultry manure and soil mulching on soil properties, physiological responses, yields and water-use efficiencies of sorghum plants under water stress. *Communications in Soil Science and Plant Analysis*, *50*(20), 2626-2639

Eslami, S. V. (2014). Weed management in conservation agriculture systems. In *Recent advances in weed management* (pp. 87-124). *Springer*, New York, NY.

Farooq, M., Khan, I., Nawaz, A., Cheema, M. A., & Siddique, K. H. (2020). Using sorghum to suppress weeds in autumn planted maize. *Crop protection*, *133*, 105162.

Greenly K, Rakow D (1995) The effects of mulch type and depth on weed and tree growth. *J. Arboric*. 21:225–232

Heap I (2014) Herbicide resistant weeds. In: Pimentel D, Peshin R (eds) Integrated pest management. *Springer*, Dordrecht, pp 281–301

Henderson L (2001) Alien weeds and invasive plants. Plant Protection Research Institute Handbook No. 12. Paarl Printers, Cape Town, South Africa

Hoffman M. L&Buhler D. D. (2002) Utilizing sorghum as a functional model of crop–weed competition. I. Establishing a competitive hierarchy. *Weed Sci 50*:466–472

Holm L. G, Plucknett D. L, Pancho J. V & Herberger JP (1997) Sorghum halepense L. Pers. In: Holm (ed) The world's worst weeds, distribution and biology. The University Press of Hawaii, Honolulu, pp 54–61

Huang H, Ling T, Wei S, Zhang C (2015) A new 4-oxazolidinone from *Sorghum halepense* (L.) Pers. *RecNat Prod* 9:247–250

Islam, M. T., & Faruq, A. N. (2009). Effect of some cultural practices for the management of mungbean yellow mosaic disease. *Journal of Sher-e-Bangla Agricultural University*, *3*(1).

Kader M. A, Singha A, Begum M. A, Jewel A, Khan F. H &Khan N. I (2019). Mulching as water-saving technique in dry land agriculture. Bulletin of the National Research Centre 43:1–6

Karim, Z., Akanda, A.M., Hossain, M.S., Islam, M. M. & Rahman, M.M.E. (2006). Effect of polythene mulch on the management of Tomato purple vein virus (TPVV) in the field. Bangladesh *Journal of Plant Pathology*. *22(*1&2)*:*79-83.

Khairnar, C. B., Goud, V. V., & Sethi, H. N. (2014). Pre-and post-emergence herbicides for weed management in mungbean.

Kumar, V., Tripathi, S. S., Sachan, H. K., & Singh, V. P. (2008). Effect of weed managment techniques on weed dynamics and green foder yield of sorghum. *Indian Journal of Weed Science*, *40*(1&2), 72-74.

Lamont W. J. (2005) Plastics: modifying the microclimate for the production of vegetable crops. *Hortic. Technol.* 15:477–481

Lightfoot D. R. (1994) Morphology and ecology of lithic-mulch agriculture. *Geo. Rev.* 25:172–185

Mahmood, A., Cheema, Z. A., Mushtaq, M. N., & Farooq, M. (2013). Maize–sorghum intercropping systems for purple nutsedge management. *Archives of Agronomy and Soil Science*, *59*(9), 1279-1288.

Mihovsky T, Pachev I (2012) Reduced tillage practices. *Banat's J Biotech* 3:49–58

Mistaskas, M. B., C. E. Tsolis., E. G. llis, D. A. Christos. 2003, Interference between corn and Johnsongrass (*Sorghum halepense* L.) from seed or rhizomes. Weed Sci. (51): 540-545

Mohtisham A, Ahmad R, Ahmad Z, Aslam M. R. (2013) Effect of different mulches techniques on weed infestation in aerobic rice (*Oryza sativa* L.). *Ame-Eur. J. Agric. Environ. Sci. 13*: 153-157

Naeem, M., Farooq, M., Farooq, S., Ul-Allah, S., Alfarraj, S., & Hussain, M. (2021). The impact of different crop sequences on weed infestation and productivity of barley (Hordeum vulgare L.) under different tillage systems. *Crop Protection*, *149*, 105759.

Nalayini P. (2007) Poly-mulching a case study to increase cotton productivity. Senior scientist, Central Institute for Cotton Research, Regional Station, Coimbatore

Ngouajio M. &McGiffen M.E. (2004) Sustainable vegetable production: effects of cropping systems on weed and insect population dynamics. *Acta.Hortic*. 638:77–83

Novak R., Dancza I., SzenteyL.&Karaman J. (2009) Arable weeds of Hungary. The 5th National Weed Survey (2007–2008). Ministry of Agriculture and Rural Development, Budapest, Hungary

Pannacci, E., & Tei, F. (2014). Effects of mechanical and chemical methods on weed control, weed seed rain and crop yield in maize, sunflower and soyabean. *Crop protection*, *64*, 51-59.

Penner, D. (1994). Herbicide action and metabolism. In Turf Weeds and Their Control; ASA, CSSA, Eds.; American Society of Agronomy and Crop Science Society of America: Madison, WI, USA, pp. 37–70

Rathore A. L, Pal A. R. &Sahu K. K. (1998). Tillage and mulching effects on water use, root growth, and yield of rain-fed mustard and chickpea grown after lowland rice. *J. Sci. Food. Agric. 78*:149–161

Shahzad, M., Jabran, K., Hussain, M., Raza, M. A. S., Wijaya, L., El-Sheikh, M. A., &Alyemeni, M. N. (2021). The impact of different weed management strategies on weed flora of wheat-based cropping systems. *Plos One*, *16*(2), e0247137.

Shapiro, S.S.,&Wilk, M.B. (1965). An analysis of variance test for normality (complete samples). *Biometrika. 52*, 591–611. [CrossRef]

Singh, G., Aggarwal, N., & Ram, H. (2014). Efficacy of postemergence herbicide imazethapyr for weed management in different mungbean (Vigna radiata) cultivars. *Indian Journal of Agricultural Sciences*, *84*(4), 540-543.

Soltanpour, P. N., & Workman, S. (1979). Modification of the NH4 HCO3- DTPA soil test to omit carbon black. *Communications in Soil Science and Plant Analysis*, *10*(11), 1411-1420.

Steel, R., Torrei, J. & Dickey, D. (1997). Principles and Procedures of Statistics A Biometrical Approach; McGraw-Hill: New York, NY, USA, 1997

Uludag A., Gozcu D., Rusen M., Guvercin R.S. & Demir A. (2007).The effect of Johnsongrass densities (*Sorghum halepense* L. Pers.) on cotton yield. Pak J *Biol. Sci. 10*:523–525

Unger, P. W., & Jones, O. R. (1981). Effect of soil water content and a growing season straw mulch on grain sorghum. *Soil Science Society of America Journal*, *45*(1), 129-134

UremisI., Arslan M., Uludag A. & Sangun M. (2009).Allelopathic potentials of residues of 6 brassica species on johnsongrass [*Sorghum halepense* (L.) Pers.]. *Afr.J.Biotechnol. 8*:3497–3501

Valverde B. E., &Gressel J., (2006) Dealing with the evolution and spread of *Sorghum*halepense glyphosate resistance in Argentina. http://www.sinavimo.gov.ar/files/senasareport2006.pdf

Vasileiadis, V. P., Froud- Williams, R. J., &Eleftherohorinos, I. G. (2012). Tillage and herbicide treatments with inter- row cultivation influence weed densities and yield of three industrial crops. *Weed biology and Management*, *12*(2), 84-90.

Vila-Aiub M. M., Gundel P. E., Yu.Q.&Powles S. B. (2013). Glyphosate resistance in *Sorghum halepense* and *Lolium rigidum* is reduced at suboptimal growing temperatures. *Pest Manag. Sci.69*:228–232

Xu, G. W., Zhang, Z. C., Zhang, J. H., & Yang, J. C. (2007). Much improved water use efficiency of rice under non- flooded mulching cultivation. *Journal of Integrative Plant Biology*, *49*(10), 1527-1534.

Yaqub, F., & Shahzad, S. (2009). Effect of solar heating by polyethylene mulching on sclerotial viability and pathogenicity of Sclerotium rolfsii on mungbean and sunflower. *Pak. J. Bot*, *41*(6), 3199-3205.

Zimdahl, R. L. (2018). Fundamentals of weed science. *Academic press*.