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

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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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

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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 treatment under wheat-mungbean cropping system. Johnson grass competition had a significant impact on growth and grain yield of both mungbean and sorghum. The crop yield parameters; 100 grain weight and grain yield were lowest in the non-treated treatment (control), while the greatest values of these parameters were recorded in the plastic sheet mulch and post emergence herbicide treatments with wheat-mungbean cropping system. Similarly, soil building attributes; available nitrogen, available phosphorus, available potassium and organic matter content were positively affected by the interaction of plastic sheet mulch + wheat-mungbean cropping system. Besides this, benefit-cost ratio of the research shows that wheat-mungbean cropping system with application of plastic sheet mulch and post emergence herbicide also proved to be economically feasible. Overall, we have concluded that wheat-mungbean and wheat-sorghum are most resilient cropping system with the implementation of plastic sheet mulch and Post Emergence Herbicide to suppress the spread of Johnson grass under changing climatic scenarios.

Keywords: Johnson grass; crop yield; soil health; cereal-legume cropping systems; climate change, economic feasibility.

1. 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 [1]. 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 [2]. It is ranked sixth among the worst weeds in whole world that has infested 30 different crops in 53 countries and invading millions of hectares [3]. It was introduced as a perennial fodder crop, but its invasive and tenacious nature has made it a nuisance to agricultural productivity [4,5]. Because of its high core competencies and allelopathic potential, *Sorghum halepense* is eminent for having a detrimental impact on neighboring plant growth and development [6,7]. In cultivated regions, it has resulted in significant yield losses in economically important crops such as wheat, soybean, maize, cotton, vegetables, and fruits [8]. When the cyanide content of weed is high, grazing on *S. halepense* causes harm to cattle, sheep, and horses during winter [9]. 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 [10,11]. 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 [12,13].

Cropping systems are described as the pattern of crops that are grown throughout the large area, as well as the methods used to cultivate crops [14]. 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 [14]. 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. Mono cropping has a number of negative implications, including poor soil qualities, increased fertilizer and pesticide usage, weed and insect infestations, and decreased crop yields [14].

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" [15]. 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 [16,17]. 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 [18]. 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 [19,20].

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 [21,22]. 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 cumulative quantity of mulch [21,22].

2. MATERIALS AND METHODS

2.1 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.

Three cropping systems (CS) were used in this experiment: wheat-sorghum (CS_1), wheat-mungbean (CS_2) and wheat-fallow (CS_3). Four weed control techniques were factorial paired with the CS: control (C), deep ploughing (DP), post emergence herbicide (PEH), and plastic sheet mulch (PSM). The experiment was set up in a split-plot arrangement. 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 30m x 20m. 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. Post emergence herbicide (PEH) was applied to crops according to the biology. For sorghum mesotrione + atrazine was applied @ 720 ml/ha and for mungbean quizalofop pmethyl was used @ 1.09 L/ha. We had applied glyphosate @ 2.47 L/ha to the fallow plot. Three doses were applied each after 20 days of application and first dose will be applied 15 days after sowing.. 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.

2.2 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%.

2.3 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 of mungbean, 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.

2.4 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.

2.5 Benefit Coast Ratio

It is the indicator of relationship between the total costs the benefit of the project or research completed. It was estimated through given formula:

$$\text{BCR} = \frac{\text{Expected Benefit}}{\text{Expected Cost}}$$

Table 1. Crop husbandry of different crops encompassed in 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

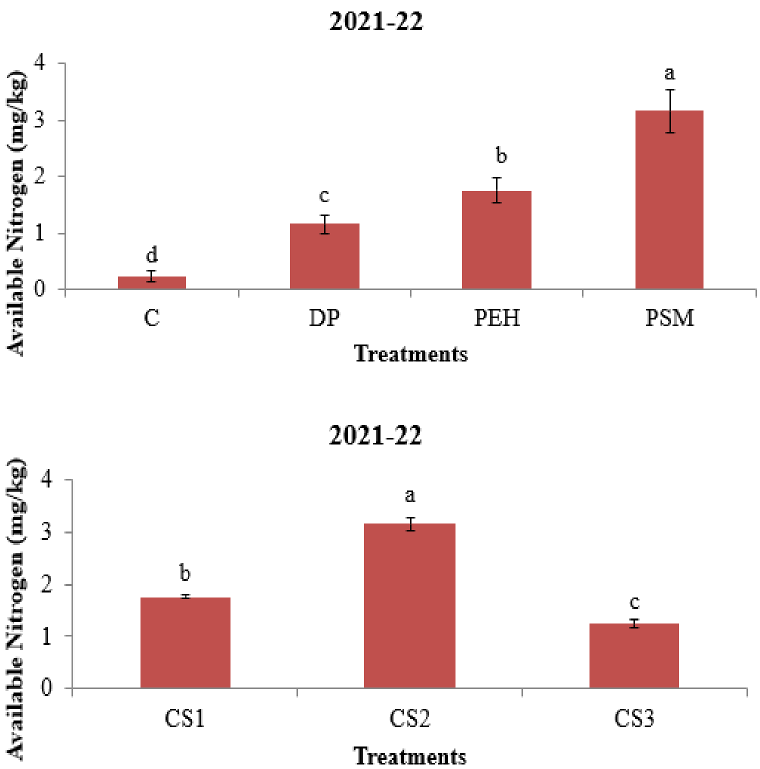


Fig. 1a, b. Effect of numerous management practices (a) and cropping systems (b) on available nitrogen (mg/kg)

C = Control, DP = Deep Ploughing, PEH = Post Emergence Herbicide, CS_1 = Wheat-Sorghum, CS_2 = Wheat-Mungbean, CS_3= Wheat-Fallow. Any two means sharing different letters are statistically different ($p \leq 0.05$) from each other

2.5 Soil Analysis

Composite soil samples (0–15 cm depth) were obtained from each experimental unit for postharvest soil analysis of Available N, P, K and soil organic content (SOM). 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.

2.6 Statistical Analysis

Utilizing Statistical Software, IBM SPSS and R, data were statistically examined in order to identify substantial variability among various parameters. The least significant difference test was used to compare the means.

3. RESULTS AND DISCUSSION

3.1 Soil Properties

During the season of study, different management practices (MP) and cropping systems (CS) had a substantial influence on available nitrogen. PSM had the greatest nitrogen value among management methods, whereas C had the lowest. In cropping systems (CS), CS_2 had the highest value of plant available nitrogen while cropping system CS_3 had the lowest value (Fig. 1a, b).

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 7.63 to 19.40 mg/kg. The PSM and PEH produced the greatest values of available P, whereas C has the minimum value of available P. Similar to this, among the several CS included in the study, available P varied from 5.90 to 19.4 mg/kg. The minimum and maximum values for available P were obtained for C_2 and C_3 cropping systems, respectively (Fig. 2a, b).

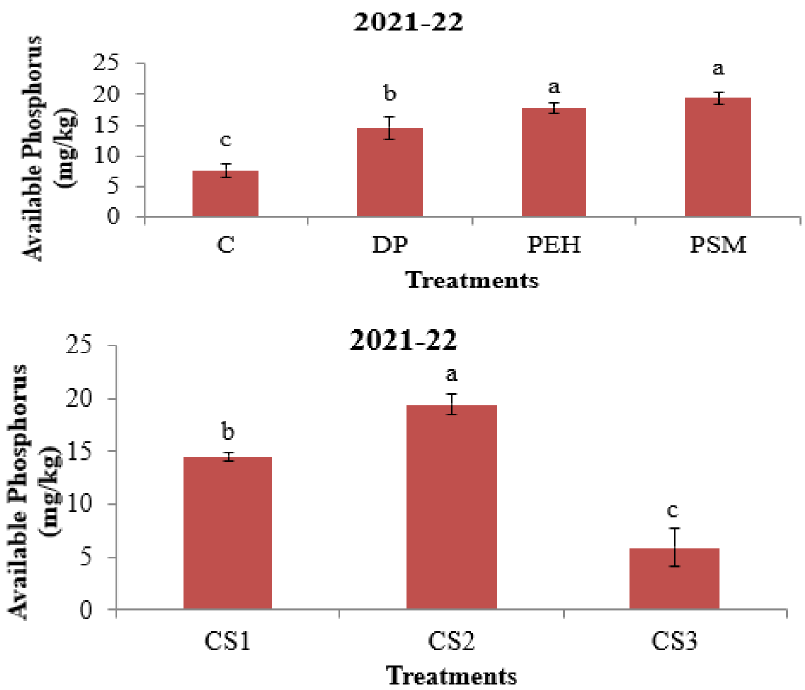
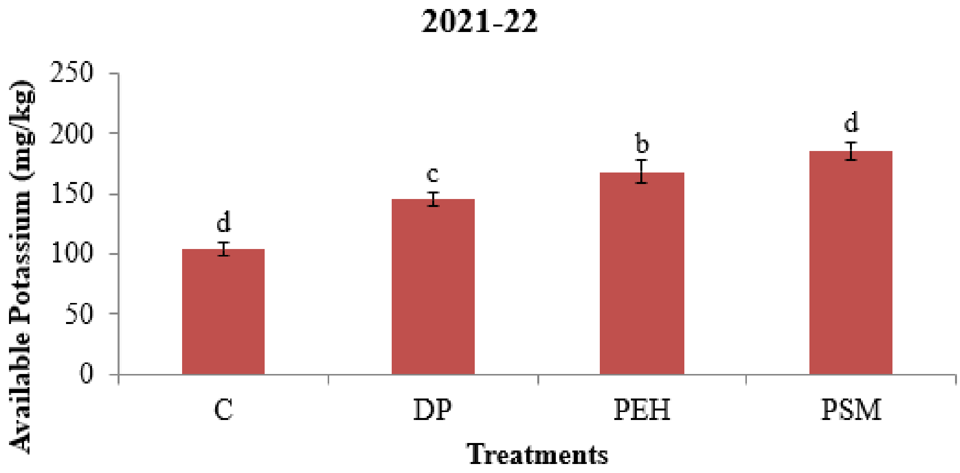


Fig. 2a,b. Effect of numerous management practices (a) and cropping systems (b) on available phosphorus (mg/kg)

C = Control, DP = Deep Ploughing, PEH = Post Emergence Herbicide, CS_1 = Wheat-Sorghum, CS_2 = Wheat-Mungbean, CS_3= Wheat-Fallow. Any two means sharing different letters are statistically different ($p \leq 0.05$) from each other

Different management practices (MP) and cropping systems (CS) had a substantial influence on plant available potassium. PSM had the greatest potassium level among management treatments, whereas C had the lowest. Cropping system CS_2 had greatest value of potassium; however the CS_3 cropping system had the lowermost value. Similarly, available K ranged among the several CS included in the study from 121.43 to 185.81 mg/kg. The C_2 and C_3 cropping systems had estimated with maximum and minimum values for available K through the time of the experiment, respectively (Fig. 3a, b).

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 organic matter, whereas C recorded the lowest. The CS_2 cropping system had the highest value of soil organic matter, whereas the CS_3 cropping system had the lowest value.



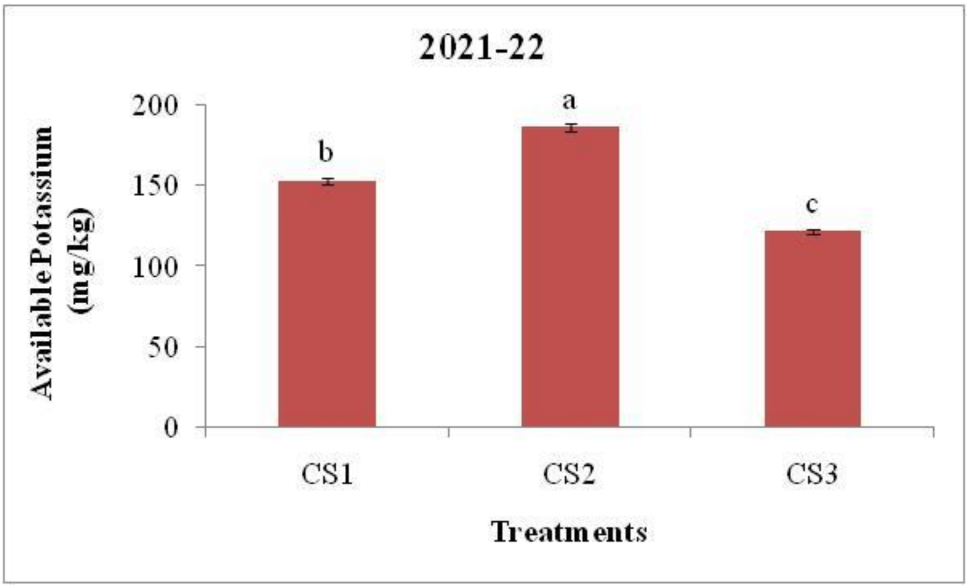
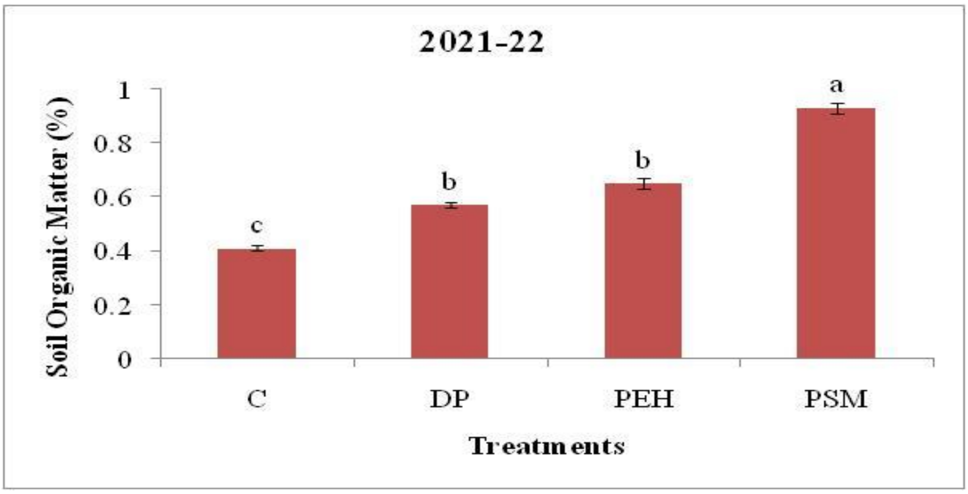


Fig. 3a,b. Effect of numerous management practices (a) and cropping systems (b) on available potassium (mg/kg)

C = Control, DP = Deep Ploughing, PEH = Post Emergence Herbicide, CS_1 = Wheat-Sorghum, CS_2 = Wheat-Mungbean, CS_3= Wheat-Fallow. Any two means sharing different letters are statistically different (p ≤ 0.05) from each other



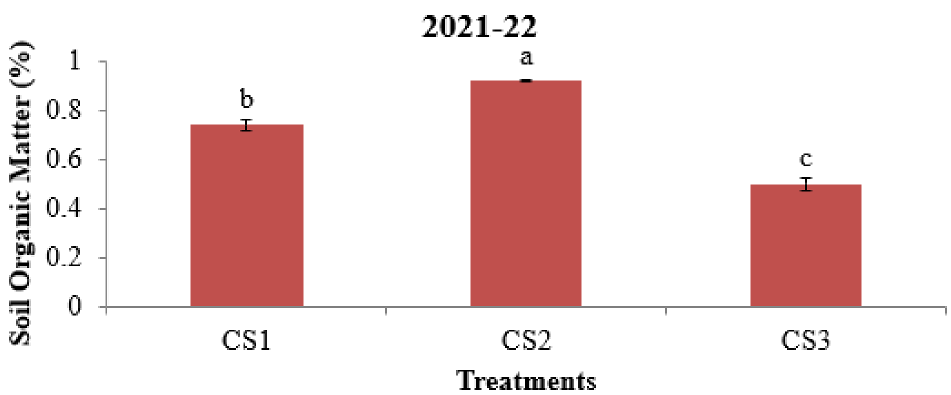


Fig. 4a,b. Effect of numerous management practices (a) and cropping systems (b) on soil organic matter (%)

C = Control, DP = Deep Ploughing, PEH = Post Emergence Herbicide, CS_1 = Wheat-Sorghum, CS_2 = Wheat-Mungbean, CS_3= Wheat-Fallow. Any two means sharing different letters are statistically different ($p \le 0.05$) from each other

3.2 Weed Parameters of Johnson Grass

3.2.1 Plant density (plants per m^2)

Various management treatments and cropping system had significant effect on plant density of Johnson grass. However, lowest plant density was recorded in PSM which was followed by PEH while highest plant density was noted in C treatment followed by DP (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_1 throughout the growing season (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 43 to 7 plants per m^2 (Table 2). During the year of the research, all CS had the lowest plant density of Johnson grass with PSM, followed by PEH (Table 2). All CS had the maximum plant density of Johnson grass with C treatment, whereas CS_1 had the lowest (Table 2). CS_3 was the most afflicted cropping system overall, however CS_1 was slightly affected cropping system in this experiment.

3.2.2 Plant height (cm)

The interactive effect of cropping systems and management treatments in the experimental year considerably influenced plant height of observed Johnson grass. The plant height varied from 223.76 to 73.17 cm (Table 3). All CS measured the least plant height of Johnson grass using PSM, which was then followed by PEH (Table 7). All CS recorded the optimal plant height of Johnson grass with C treatment, but the CS_1

recorded the minimum value (Table 3). Consequently, CS_3 had the highest plant height across all cropping systems, whereas CS_1 had the lowest plant height throughout all cropping systems.

3.2.3 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 treatment. 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 CS_1 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) profoundly influenced plant fresh weight of observed Johnson grass. The fresh weight of the plant varied from 441.73 to 132.44 g (Table 4). All CS measured the minimum plant height of Johnson grass using PSM, which was then followed by PEH (Table 8). All CS recorded the optimal plant height of Johnson grass with C treatment, but the CS_1 recorded the lowest values (Table 4). Furthermore, CS_3 had the highest plant height among all cropping systems, while CS_1 had the lowest plant height across all cropping systems.

3.2.4 Plant dry weight (cm)

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

Plant dry weight was changed drastically during both study years due to the interaction between cropping systems (CS) and management treatments (T). The plant dry weight varied from 93.49 to 11.53 g, respectively (Table 5). During this period of the study, PSM was used to record the minimum plant height of Johnson grass, followed by PEH (Table 5). CS_1 was reported with lowest value of plant dry weight, although all CS recorded the optimal plant height of Johnson grass with C treatment (Table 5). In general, CS_3 had the highest average plant dry weight across all cropping systems, whereas CS_1 had the lowest average plant dry weight across all cropping systems.

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

	CS_1	CS_2	CS_3	Mean
C	22.66d	30.33bc	43.00a	32.00a
DP	13.67ef	22.00d	32.67b	22.78b
PEH	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, PEH = Post Emergence Herbicide, PSM = Plastic Sheet Mulch, CS_1=wheat-sorghum, CS_2=wheat-mungbean, CS_3= wheat-fallow, CS = cropping-systems and T= management treatments

Table 3. Effect of different cropping systems and management practices on plant height (cm) of Johnson grass

	CS_1	CS_2	CS_3	Mean
C	194.42bc	217.64ab	223.74a	211.93a
DP	167.15d	185.08cd	200.06abc	184.10b
PEH	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, PEH = Post Emergence Herbicide, PSM = Plastic Sheet Mulch, CS_1=wheat-sorghum, CS_2=wheat-mungbean, CS_3= wheat-fallow, CS = cropping-systems and T= management treatments

Table 4. Effect of different cropping systems and management practices on plant fresh weight (g) of Johnson grass

	CS_1	CS_2	CS_3	Mean
C	403.90ab	422.88ab	441.73a	422.84a
DP	342.04c	355.54c	389.08bc	362.22b
PEH	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, PEH = Post Emergence Herbicides, PSM = Plastic Sheet Mulch, CS_1=wheat-sorghum, CS_2=wheat-mungbean, CS_3= wheat-fallow, CS = cropping-systems and T= management treatments

Table 5. Effect of different cropping systems and management practices on plant dry weight (g) of Johnson grass

	CS_1	CS_2	CS_3	Mean
C	67.11c	80.96ab	93.49a	80.52a
DP	62.12c	71.45bc	85.19a	72.92a
PEH	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, PEH = Post Emergence Herbicides, PSM = Plastic Sheet Mulch, CS_1=wheat-sorghum, CS_2=wheat-mungbean, CS_3= wheat-fallow, CS = cropping-systems and T= management treatments

3.3 Agronomic Parameters of Mungbean

3.3.1 Plant height (cm)

Data on the subject of plant height of mungbean as prejudiced by management practices is presented in Fig. 5. Analysis of variance (ANOVA) of the data revealed that management practices significantly affected the plant height of mungbean. Plots sown where plastic sheet mulch treatment was applied produced plants with maximum plant height of 58.46 cm, while minimum plant height (37.17 cm) was observed in control where nothing was applied as management practices.

3.3.2 100 grain weight (g)

Management techniques considerably changed the100grain weight. Different management practices considered in the study varied the 100 grain weight from 5.02 to 3.26 g in the growing year. The greatest values of 100 grain weight were obtained from the PSM (5.02 g) and PEH (4.08 g), whilst the lowest values were obtained from the control (C) (3.26 g) (Fig. 6).

3.3.3 Grain yield (kg/ha)

In both research years, grain yield varied dramatically depending on management strategies. Among the various management approaches, grain yield varied between 1610.7 and 810.27 kg/ha. The maximum grain yield was produced by the PSM (1610.17 g) and the PEH (1150.52 kg/ha), whereas the C (810.27 kg/ha) produced the lowest average grain yield (Fig. 7).

3.4 Agronomic Traits of Sorghum

3.4.1 Plant height (cm)

Data regarding plant height of mungbean as influenced by management practices are presented in Fig. 8. Analysis of variance (ANOVA) of the datarevealed that management practices significantly affected the plant height of mungbean. Plots sown where PEH treatment was applied produced plants with maximum plant height of 229.96 cm while minimum plant height 208.46 cm was found in case of control where nothing was applied as management practices.

3.4.2 100 grain weight (g)

Analysis of variance (ANOVA) regarding 100 grain weight showed that management treatments were significant. Maximum 100 grain weight was 3.81 g recorded in PSM during. It was followed by PSM having 100 grain weight 3.55 g. Furthermore, the 100-grain weight of 2.70 g were found in control (C) during the period of experiment (Fig.9)

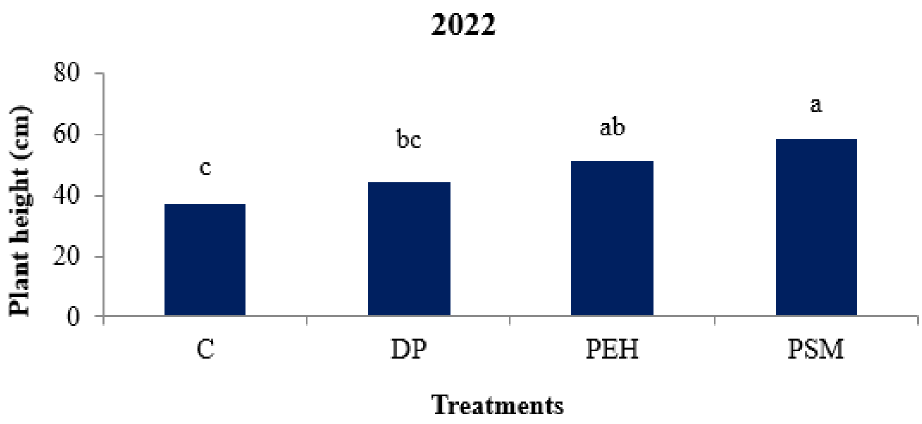


Fig. 5. Plant Height (cm) of mungbean as affected by the various management treatments
C = Control, DP= Deep Ploughing, PEH= Post Emergence Herbicides, PSM= Plastic Sheet Mulch. Error bars indicate the LSD 5% values

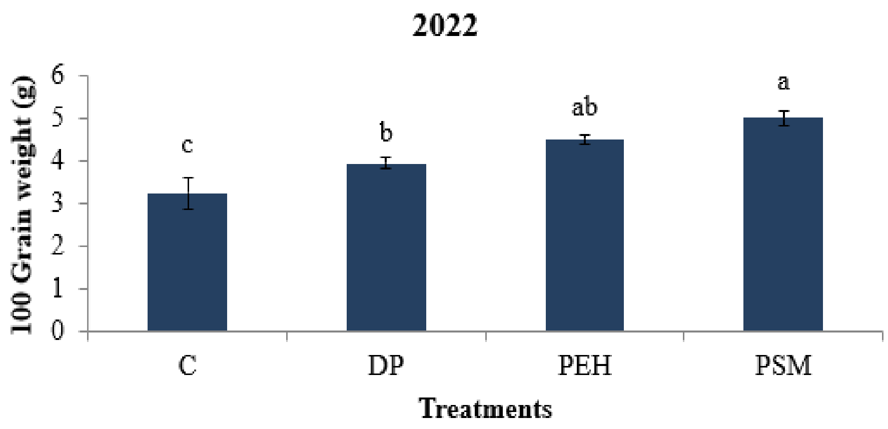


Fig. 6. 100 grain weight (g) of mungbean as affected by the various management treatments
C = Control, DP= Deep Ploughing, PEH= Post Emergence Herbicides, PSM= Plastic Sheet Mulch. Error bars indicate the LSD5% values

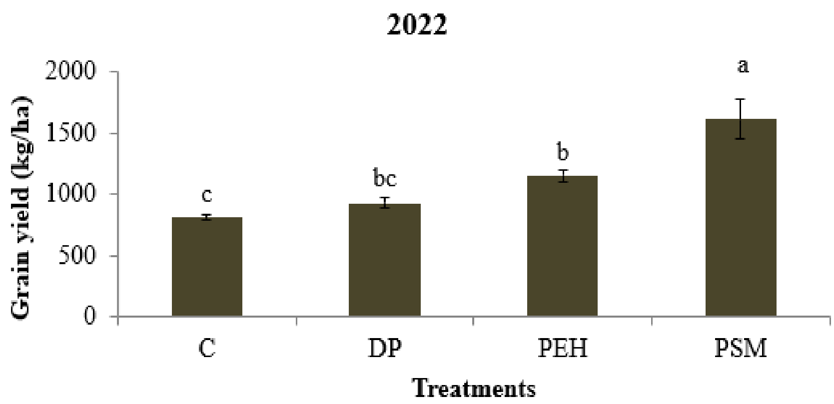


Fig. 7. Grain yield (kg/ha) of mungbean as affected by the various management treatments
C = Control, DP= Deep Ploughing, PEH= Post Emergence Herbicides, PSM= Plastic Sheet Mulch. Error bars indicate the LSD 5% values

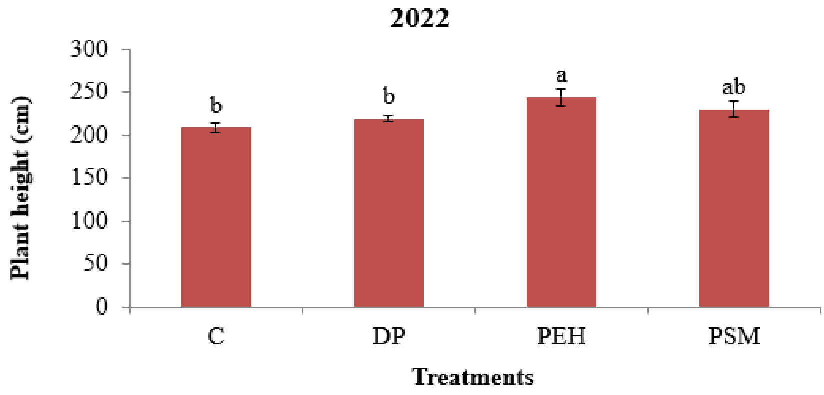


Fig. 8. Plant Height (cm) of sorghum as affected by the various management treatments
C = Control, DP= Deep Ploughing, PEH= Post Emergence Herbicides, PSM= Plastic Sheet Mulch. Error bars indicate the LSD 5% values

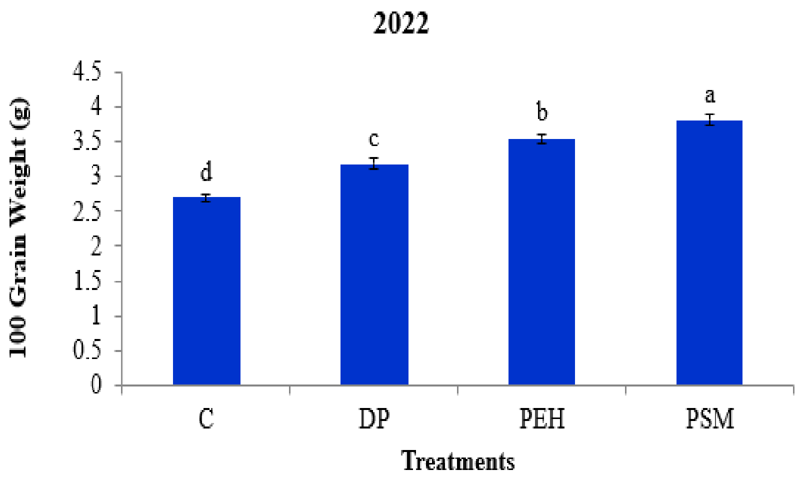


Fig. 9. 100 grain weight (g) of sorghum as affected by the various management treatments
C = Control, DP= Deep Ploughing, PEH= Post Emergence Herbicides, PSM= Plastic Sheet Mulch. Error bars indicate the LSD5% values

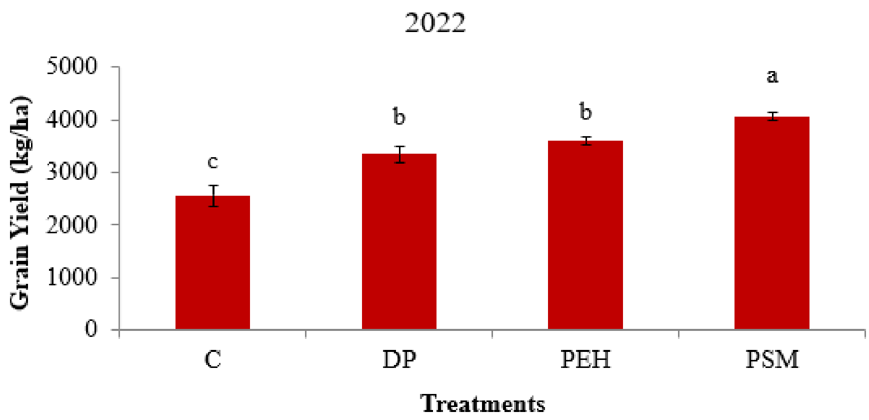


Fig.10. Grain yield (kg/ha) of sorghum as affected by the various management treatments
C = Control, DP= Deep Ploughing, PEH= Post Emergence Herbicides, PSM= Plastic Sheet Mulch. Error bars indicate the LSD 5% values

Table 6. Economic evaluation and benefit cost ratio of different cropping systems and management practices

Treatments	Winter Output (kg/acre) (A)	Summer Output (kg/acre) (B)	Total Output (A+B)	Total Cost	Total Benefit (acre^{-1})	Benefit Cost Ratio (BCR)
CS_1 + C	37268.91	91832.24	129101.15	35750	93351.00	2.611
CS_1 + DP	37268.91	116934.63	154203.54	37750	116453.54	3.084
CS_1 + PEH	37268.91	117979.74	155248.65	42050	113198.65	2.692
CS_1 + PSM	37268.91	129835.48	167104,39	55550	111554.39	2.008
CS_2 + C	38222.81	82438.28	120661.09	36250	84411.09	2.328
CS_2 + DP	38222.81	94469.85	132692.66	38250	94442.66	2.469
CS_2 + PEH	38222.81	127397.31	165620.12	40750	124870.12	3.064
CS_2 + PSM	38222.81	148791.98	187014.79	54250	132764.79	2.447
CS_3 + C	48086.30	0.0	48086.30	27750	20336.30	0.732
CS_3 + DP	48086.30	0.0	48086.30	29750	18336.30	0.616
CS_3 + PEH	48086.30	0.0	48086.30	32250	15836.30	0.491
CS_3 + PSM	48086.30	0.0	48086.30	45750	2336.30	0.051

3.4.3 Grain yield (kg/ha)

Grain yield varied dramatically depending on management strategies. Among the various management approaches examined in the research, it varied between 2214.6 kg/ha between the 4061 and 2555.18 kg/ha during the growing season. The PSM and PEH produced the greatest grain yields, (3595.99 and 4061 kg/ha), whereas control (C) (2555.18 kg/ha) produced the lowest grain yield (Fig. 10).

3.5. Benefit Cost Ratio (%)

This whole estimate of BCR was average to one acre area instead of the area of experimental plots. In this experiment permanent cost for all treatments includes land preparation charges, seed cost, seed sowing cost, thinning and weeding charges, pesticide charges, fertilizers charges, deep ploughing charges, plastic sheet charges, and herbicides and harvesting charges. Land preparation done with cultivator which plough and plank the field at same time within one and half hour and it charges PKR 2500 for winter season and PKR 3200 for each summer season plot. Seed costs for PKR 4000, 3500 and 3000 for wheat, mungbean and sorghum respectively. Seed sowing done with drill in both winter summer season crops which charges PKR 2700, 3500 and 3500 for wheat, mungbean and sorghum correspondingly for one acre. Application of fertilizer costs about PKR 6800 and 1850 for DAP and Urea for each crop. After seed sowing thinning was done manually with four workers within three days for wheat only. Each labor cost for PKR 700 for each day. PKR for total labor cost. Combine harvester cost for PKR. 3500 and packing of grains costs PKR 1500 hence; total harvesting charges was PKR 5000 for both season crops. Some input costs were different which is called as variable inputs costs. In control treatment there was no application of management practices was done hence variable cost were zero for control treatment but all permanent costs were same. Management practices and cost were different for different treatments. Treatments where deep ploughing was applied cost extra PKR 2000 for each crop in summer season. Similarly, application of herbicides in summer season which was used as treatment cost PKR 4500 for all three applications. Applying of plastic sheet as mulch was very expensive which cost PKR 180 per kg with total cost of PKR 14000 for each plot in summer season (Table 6). Yield was in kilograms per hectare and it was converted into mounds per hectare. Sale rate tor one mound of wheat was PKR 1800 and sale rate for straw was PKR 380 per mound. In summer season, mungbean and sorghum was sown and one plot was remained fallow. Market rate of mungbean grains was PKR 4000 per mound and its straw was PKR 250 per mound. Similarly, grain sorghum had market rate of PKR 2400 per mound but fallow had given no return. At this sale rates maximum profit was At this sale rate maximum profit were obtained from CS_1 x DP (BCR =3.084) which was followed by CS_2 x PEH (BCR =3.064) and CS_1 x PSM (BCR = 2.692) while minimum profit was achieved by CS_3 x PSM (BCR = 0.051) which was followed by CS_3 x PEH (BCR = 0.491) and CS_3 x DP (BCR = 0.616) (Table 6)

4. DISCUSSION

Shahzad et al. [23] 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.[24]showed that phenolic compounds present in sorghum played pivot role in suppression of plant height of these noxious weeds. Our outcomes are in proximity with the results of Azadbakhtet al. [25] and Asif et al.[26] who found that weed density can be reduced by using plastic sheet mulch on soil surface during sowing. Naeem et al. [27] 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. Our results are in agreement with those of Awal et al. [28]. 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, [29] reported that good to excellent control of Johnson grass was observed for applying herbicide at 8 cm and 16 cm tall Johnson grass**.**

Azad et al. [30] found that application of sheet mulch diminishes the fresh weight of Johnson grass and other summer season weeds. While Mistaskas et al. [31] found that fresh weight of Johnson grass was diminished by the early application herbicides and its fresh weight increased with greater duration of time. Similarly, Czarnota et al. [32] 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. Azad et al. [30] recorded that there was significant decrease in dry weight of weeds by the application of plastic sheet mulch as management practices. Czarnota et al. [32] 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, Mistaskas et al. [31] also reported similar results that allelopathic extract put negative affect on weeds which suppressed the plant dry of weeds.

Yaqub & Shahzad [33] indicated a gradual increase in plant height of mungbean when applied with plastic sheet due to solarization which results in reduction of attack of pests and emergence of weeds. Islam & Faruq [34] also recorded the similar results of increased plant height in mungbean by the application of different plastic sheets. Agele et al. [35] also observed that plastic mulches maximize the plant height of crops and Mohtisham et al. [36] revealed that plastic sheet mulch improves the plant height to larger extent in rice crop. Similar findings were also reported by Kumar et al. [37] that plant height significantly increased by the application of post emergence herbicide on sorghum. Similarly, Singh et al. [38] also suggested when post emergence herbicide 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. [39] during the application of Post Emergence Herbicide on crop under observation.

Burnside & Wicks [40] had found that application of plastic sheet mulch also put substantial difference on the 100-grain weight of sorghum but El- Samnoudi et al. [41] 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. 15. Additionally, Abdelrahman et al. [42] also found that applying sheet mulch increases the 100-grain weight in almost all crops. The results of Mohtisham et al. [36] are in line with our research, 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. [43] where mulches improved the 100 grain weight of crop.

Unger & Jones [44] 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. [41] 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.

Karim et al. [45] 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 & Faruq [34] which showed that application of polythene sheet as mulch increased the grain yield of mungbean by 11.73 %. Karim et al. [45] 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 [36]. In sunflower grain yield (24 and 19 t/ha) has been recorded when plastic sheet mulch was applied [35].

5. CONCLUSION

The results of this study indicated that Johnson grass 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 7 plants/m^2 and in CS_2 it was 12.60 plants/m^2 with the addition of plastic sheet mulch. 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 1610.17 kg/ha and sorghum yield was 4061 kg/ha during both study years. The plant density of Johnson grass in CS_1 + PSM was 69.10 % was lower than control while it was 58.25 % lower than control in CS_2 + PSM. The yield of mungbean was 49.67 % greater than control while sorghum yield has increased yield of 7.10 %. The most economically effective treatments were CS_1 x DP (BCR =3.084), CS_2 x PEH (BCR =3.064) and CS_1 x PSM (BCR = 2.692.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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