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Full Length Article

Assessing the Agronomic Consequences of Delayed Removal of Parthenium from Forage Sorghum (*Sorghum bicolor*)

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Abstract

Parthenium (*Parthenium hysterophorus* L.) is a serious invasive weed of sorghum and other crops in Pakistan. This two-year field study was conducted to investigate the impact of different weed-crop competition durations (4, 5, 6, 7, 8 weeks after emergance (WAE) and full season competition on parthenium growth, nutrient uptake, forage sorghum yield and quality traits. The highest parthenium dry biomass (35.18 and 44.23 g m^{-2}) and nitrogen, phosphorus, and patassium uptake was recorded under its competition during the full crop growing season. Forage sorghum quality and yield were affected by increasing the duration of competition with parthenium weed. The plant height, fresh and dry forage yield, leaf area $plant^{-1}$, leaf to stem ratio, total ash contents and crude protein contents of forage sorgham were higher in weed free control, and started to decrease with weed competition duration of 5 WAE or more, and decrease was more at higher weed competition durations. The contents of acid detergent fiber (ADF) and neutral detergent fiber (NDF) of forage increased as competition period increased which showed forage quality deterioration. The period of 5 weeks competition seemed as critical period of competition beyond which parthenium caused more than 5% fresh forage yield losses. In conclusion, parthenium should be controlled within 1st five weeks after the emergence of crop to avoid quality and yield losses of forage sorghum.

Keywords: Competition duration; Forage quality; Forage yield; *Parthenium hysterophorus;* Sorghum

Introduction

Sorghum (*Sorghum bicolor* L.) belongs to family Poaceae which is globally cultivated including Pakistan for grain and fodder crop. Sorghum can be used as grain, feed for livestock, making silage, alcohol and sugar extraction. Average yield of forage sorghum (40 tons ha^{-1}) in Pakistan is very low (Ayub and Shoaib 2009). Weed infestation is among the yield limiting factors of sorghum and causes enormous yield and quality losses in many field crops (17–64%) of Pakistan (Abbas 2013).

Globally, Parthenium (*Parthenium hysterophorus* L.) is an invasive weed and becoming problematic in sorghum and many other summer crops in Pakistan (Bajwa et al. 2019, 2020a, b). Parthenium weed is an invasive weed of different world parts including Pakistan because of its unique reproductive, competitive ability, adopting C_3 and C_4 cycle, high tolerance ability to biotic and abiotic stress, high allelopathic potential and genetic diversity (Bajwa *et al*. 2016). Like other cropping weeds, parthenium also reduce quality and yield of fresh forage up to 18–90% in fodder crops (Tamado *et al*. 2002; Asif *et al*. 2017). This weed reduces yield and quality of crops by competing with main crop and releasing allelochemicals in soil which reduces growth and development of crop (Tanveer *et al.* 2015). It causes yield and quality losses in pigeon pea (*Cajanus cajan* L.), maize (*Zea mays* L.), sunflower (*Helianthus annuus* L.), sorghum, black grams (*Cicer arietinum* L.) and many other fodders (Angiras and Saini 1997; Tamado *et al.* 2002; Asif *et al*. 2017). Parthenium is very harmful and indigestible for the animals so mostly animals do not prefer to eat it. In animals several problems are caused due to parthenium eating like mouth ulcer with excessive saliva, dermatitis with skin lesion, reduction in yield of milk, tainting of and sometimes animal may die due to rupturing and hemorrhaging of internal tissues (Patel 2011). Parthenium is toxic and un-palatable for livestock so it became compulsory to control it from forage crops (Kumar 2014).

Weeds should be controlled during critical competition duration which may vary with competing plant species (Safdar *et al.* 2016). Former studies showed that in grain sorghum, 19 to 67 days are critical duration of parthenium

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crop competition and 30 to 45 days for black gram (Vivek *et al*. 2008). But if it is not controlled for whole crop growing season it can cause approximately 40 to 97% yield and quality losses of sorghum crop (Das 2008). Safdar *et al.* (2016) stated that parthenium compete and uptake the nutrients and reduced crop yield during the first 23 days after emergence of crop in maize, so controlling weeds in this duration increased maize yield. Lawrence and Sprague (2004) reported that in maize crop first 30 to 40 DAS were critical for *Amaranthus radis* L. competition. Tamado *et al.* (2002) evaluated the impact of competition duration in sorghum during 1999–2000 and concluded that duration of weed control from 19 to 69 and 40 to 57 days after emergence of sorghum had extreme benefits in the year of 1999 and 2000, respectively. Weed competition reduce quality of forage sorghum (crude protein, palatability, leaf to stem ratio) and under un-weedy condition sorghum produce high quality forage (Gholami *et al.* 2013).

According to the previous research studies, it is observed that most of research work has been done on the effect of parthenium competition duration on the grain sorghum but research on the forage sorghum is scanty. So, this research was undertaken to ascertain the impact of parthenium competition durations on the sorghum forage yield, yield components and forage quality. The findings of the research may be helpful to know the extent of forage yield and quality losses at different competition durations of parthenium and to decide the suitable time of parthenium control in forage sorghum.

Materials and Methods

Experimental site description

The field study was laid out in 2013 and 2014 during summer at Agronomy Farm, University of Agriculture Faisalabad, Pakistan. Soil of investigation site was clay loam having organic matter percentage 0.64%, pH 8.1, total N 0.04%, 7.67 mg kg^{-1} available phosphorus and 268.5 mg kg^{-1} available potassium. Average rainfall of season was 176.4 mm in 2013 and 67.9 mm in 2014.

Experimental details

The experiments comprised of six parthenium competition durations *viz*., namely 4, 5, 6, 7, 8 weeks after crop emergence (WAE) and full growth period of sorghum. For comparison a weed free control was established. Randomized completely block design (RCBD) having four replicates was selected and net plot size was 6.0 m × 2.4 m. After pre-sowing irrigation when soil reached to appropriate moisture level, uniform seed bed for sowing was prepared. The sorghum (variety Hegari) was sown at 75 kg ha^{-1} by using hand drill on 5th of June in each year and 30 cm row to row distance was maintained. Fertilizers including 90 kg of N ha^{-1} and 60 kg of P_2O_5 ha^{-1} were applied during these experiments. Whereas half dose of N with total of P was applied at seed bed preparation and half N was applied at 1st irrigation. The selected field was kept fallow in previous season and there was no history of parthenium presence on selected field. So, to attain desirable parthenium seed germination, at sowing time seed was uniformly broadcasted in all the experimental units. In all plots, after weed germination a uniform (8 plants m^{-2}) weed density was maintained except the control treatment, after that all plants of parthenium weed were uprooted from respective plots at durations of 4, 5, 6, 7 and 8 WAE. Throughout growth period of sorghum, weed free control plots were kept weed free while in whole season competition, all seedlings of parthenium were permitted to grow till sorghum crop harvest. Whole experimental plot was kept all other weed free except parthenium.

Crop harvesting and data recording

After 70 days of sowing at 50% heading stage the crop, sorghum was harvested. At harvesting time, from every treatment ten plants were selected and plant height, plant diameter and leaf area were recorded for all ten plants, after that average was taken for each parameter. Fresh yield of forage was determined by whole plot harvesting and weighed it at field. Dry matter yield of sorghum was calculated by using dry matter contents which were determined by weighing fresh and oven dried samples. Parthenium plants were uprooted from area of one-meter square at crop harvest, dried in oven and then dry biomass was recorded. At crop harvest NPK uptake by parthenium was determined by estimating NPK contents in parthenium plant samples as suggested by Williams (1984). Weed relative competitive index was determined by using formula.

$$RCI = \frac{Y_{Weed\ free} - Y_{Weed}}{Y_{Weed\ free}}\ X\ 100$$

$Y_{weed\ free}$ indicates fodder yield in weed free plot and Y_{weed} indicates fodder yield in the existence of weed.

Calculation of crude protein was performed by using AOAC (1990) recommended procedure. Crude protein % was determined by multiplying the N% determined by Kjeldahl method with a factor 6.25. For NDF, sample of one gram was kept in flask, after that NDF reagent solution at 100 mL and 0.50 g sodium sulphite was mixed with sample and then fixed the flask to a cooling condenser. Slowly heat was given to the sample for 60 min. Washed four time the residues with the help of hot distilled water and with one time by acetone and then dried. Transferred residues to an already weighed crucible and placed in oven at 105°C for approximately four h. Dried sample was kept in desiccator for about 10 min. By using following formula NDF % was taken

$$\text{Neutral detergent fiber } \% = \frac{\text{Wt. of residue}}{\text{Wt. of sample}} \times 100$$

Neutral detergent fiber residues were transferred to

500 mL flask and acid detergent solution at 100 mL was added in a conical flask and fixed to a condenser. The heat was provided for approximately 2–3 min and reduced the temperature to reflux it for one h. The suction pump was used to filter contents after removing from air condenser and washed these residues three times with distilled water and one time with the acetone. Then transferred these residues into already weighed crucible and put in oven at 105°C for one day. After drying this, for cooling kept the crucible into desiccator. By using following formula ADF % was calculated:

$$\text{ADF \%} = \frac{\text{Weight of ADF residue}}{\text{Weight of sample}} \times 100$$

Total ash contents were determined according to procedure as recommended by AOAC (1990). Placed five gram of dried sample in pre-weighed china dish (W_1) and placed at 550 to 650°C in muffle furnace until grey or white color ash was obtained. Then cooled these residues by desiccator and recorded weight (W_2). The percentage ash contents were determined as following:

$$\text{Total ash (\%)} = \frac{W2 - W1}{\text{Sample weight}} \times 100$$

Leaf and stem ratio was determined on the basis of dry biomass of leaf and stem. From every plot leaves and stem of ten plants were separated, dried in oven, and then weighed.

Statistical analysis

All of the data gathered were subjected to statistical analysis by following Fisher's analysis of variance method (Steel *et al*. 1997) and comparison among treatment means was made by using Tukey's honestly significant difference (HSD) test at 5% probability.

Results

Parthenium growth characteristics and NPK uptake

Different competition durations of parthenium in forage sorghum significantly affected the dry weight and NPK uptake of parthenium (Table 1). Parthenium dry biomass increased with extension in competition duration and weed showed highest dry biomass when competition was for entire growth season. Minimum dry biomass was produced by the parthenium when competed for 4 weeks with forage sorghum during 2013 and 2014. During sec year, the parthenium weed dry biomass was significantly greater which may be attributed to higher fresh weight and the vigorous growth of sorghum over the parthenium due to much rainfall in 1st year (2013) as compared to 2nd year (2014). Competition duration also effected significantly on NPK uptake by parthenium and uptake different amount of nutrients at different duration of competition (4 WAE - full season competition) (Table 1). Parthenium uptake of NPK increased with extending competition duration during both years. Maximum NPK uptake was determined when parthenium was allowed to compete for whole growing season while least uptake was observed when parthenium weed competed for four weeks. Moreover, the higher NPK uptake of parthenium weed during year 2014 compared to that observed in 2013 (Table 1).

Relative competivity index (RCI)

Relative competivity index linearly increased as competition period was extended during 1st and 2nd years and RCI of 1.74, 2.89% was noted at competition duration of 4 WAE during 1st and 2nd year, respectively (Table 1). Relative competivity index increased with the extension of competition duration and observed the value of 4.35, 6.87% at 5 weeks, 7.83, 9.40% at 6 weeks, 13.22, 13.02% at 7 weeks, 16.0, 14.10% at 8 weeks and 22.26, 21.16% at full season competition duration during 1st and 2nd year, respectively. The increase in reduction of yield by increasing period of parthenium competition might be due to rise in competition between inter-species for common resources during crop season (Table 1).

Yield and yield contributing traits of forage sorghum

Data related to the effect of parthenium weed competition durations on yield and yield contributing traits (plant height, stem diameter, leaf area per plant, fresh fodder and dry matter yield) of forage sorghum showed significant impact during both the year of study (Table 2). Yield contributing traits significantly reduced as the competition duration extended (4 WAE-full crop season). Maximum plant height (263.57, 241.55 cm), plant stem diameter (1.04, 01.00 cm) and leaf area per plant (3079.8, 300.3 cm^2) were recorded when there was no competition duration during both the year of study, whereas competition duration of 4 weeks was also at par with no competition (control). The effect of 8 WAE and full season competition were statistically similar on all traits. Full season competition produced minimum value of plant height (249.75, 210.54 cm) with 5.24% and 12.84% reduction, plant stem diameter (0.813, 0.812 cm) with 21.82% and 18.8% and leaf area per plant (3007.9, 2851.5 cm^2) with 2.33% and 4.96% less was recorded over control during 1st and 2nd year of the study (Table 2).

Fresh fodder yield and dry matter yield also significantly affected by different competition durations. Maximum fresh fodder yield of 57.5 tons ha^{-1}, 55.3 tons ha^{-1} and dry matter yield of 15.50 tons ha^{-1}, 13.90 tons ha^{-1} in 1st and 2nd year, respectively was recorded when no competition was impose (control) on sorghum crop although this treatment (control) and 4 weeks competition duration statistically produced similar fresh fodder yield during both the year of study. Lowest fresh fodder of 44.7 and 43.6 t ha^{-1} and dry matter yield 9.72 and 8.63 tons ha^{-1} were recorded in the case of no competition treatment during 1st and 2nd

Table 1: Influence of parthenium sorghum competition durations on parthenium dry weight, NPK uptake and weed competivity index during two growing seasons

Competition durations	Dry weight (g m^{-2})		Nitrogen uptake (kg ha^{-1})		Phosphorus uptake (kg ha^{-1})		Potassium uptake (kg ha^{-1})		Weed competivity index (%)	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Control (Weed free)	------	---------	---------	---------	---------	---------	---------	---------	---------	---------
4 WAE	15.99 f	17.01 e	6.44 f	6.97 e	0.31 e	0.65 e	4.51 f	5.44 e	1.74 c	2.89 c
5 WAE	20.45 e	20.1 e	8.41 e	8.61 e	0.51 e	0.88 e	6.15 e	6.65 e	4.35 c	6.87 c
6 WAE	23.64 d	27.11 d	10.02 d	11.84 d	0.81 d	1.40 d	7.65 d	10.10 d	7.83 c	9.40 bc
7 WAE	26.30 c	31.98 c	11.56 c	14.62 c	1.25 c	1.86 c	9.15 c	12.45 c	13.22 b	13.02 b
8 WAE	31.43 b	38.67 b	14.47 b	18.46 b	1.84 b	2.61 b	11.64 b	15.50 b	16.00 b	14.10 b
Full crop season	35.18 a	44.23 a	17.05 a	21.91 a	2.29 a	3.11 a	14.13 a	18.09 a	22.26 a	21.16 a
HSD value at 5%	2.57	3.99	1.04	2.08	0.29	0.410	1.13	1.87	5.07	5.85

The means following the same letters, within a column for each trait, did not significantly differ at 5% probability level
WAE= Weeks after crop emergence

Table 2: Influence of parthenium sorghum competition durations on forage yield and yield components of forage sorghum during two growing seasons

Competition durations	Plant height (cm)		Stem diameter (cm)		Leaf area per plant (cm^2)		Fresh fodder yield (t ha^{-1})		Dry matter yield (t ha^{-1})	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Control (Weed free)	263.57 a	241.55 a	1.04 a	1.00 a	3079.8 a	3000.3a	57.50 a	55.3 a	15.50 a	13.90 a
4 WAE	261.10 a (0.94)	234.24 ab (3.03)	1.01 ab (2.88)	0.995 a (0.5)	3050.4 b (0.95)	2975.5 ab (0.83)	56.5 a (1.74)	53.7 ab (2.89)	14.49 b (6.52)	13.15 ab (5.40)
5 WAE	259.48 b (1.55)	229.50 abc (4.99)	1.01 ab (2.88)	0.968 ab (3.20)	3039.5 c (1.31)	2941.4 a-c (1.96)	55.0 ab (4.35)	51.5 bc (6.87)	13.82 b (10.84)	11.88 a-c (14.53)
6 WAE	255.93 c (2.90)	221.50 b-d (8.3)	0.94 bc (79.62)	0.925 b (7.5)	3030.0 d (1.62)	2926.4 a-c (2.46)	53.0 b (7.83)	50.1 b-d (9.40)	12.80 c (17.42)	11.06 b-d (20.43)
7 WAE	254.43 cd (3.46)	217.44 cd (9.98)	0.898 cd (13.65)	0.840 c (9.19)	3021.3 e (1.89)	2890.3 bc (3.66)	49.9 c (13.21)	48.1 cd (13.01)	11.59 d (25.22)	10.16 cd (26.90)
8 WAE	252.32 de (4.27)	214.67 d (11.13)	0.838 de (19.42)	0.823 c (17.7)	3012.8 f (2.18)	2862.7 c (4.59)	48.3 c (16.00)	47.5 d (14.10)	10.74 e (30.71)	9.33 cd (32.88)
Full crop season	249.75 e (5.24)	210.54 d (12.24)	0.813 e (21.83)	0.812c (18.8)	3007.9 f (2.33)	2851.5 c (4.96)	44.7 d (22.26)	43.6 e (21.16)	9.72 f (37.29)	8.63 d (37.91)
HSD value at 5%	3.20	14.65	0.080	0.068	6.99	97.41	2.99	3.69	0.687	2.83

The means following the same letters, within a column for each trait, did not significantly differ at 5% probability level
WAE= Weeks after crop emergence

year, respectively. In case of dry matter yield treatment 7, 8 weeks and full season competition duration have found to be statistically similar during the 2nd year. Yield and yield contributing traits showed better performance during the 1st year as compare to 2nd year which may be attributed due to more favorable environmental condition which leads to better growth and yield as compare to 2nd year (Table 2).

Forage quality traits

Competition duration of parthenium influenced the forage quality traits of sorghum. Crude protein, total ash contents, ADF, NDF contents and leaf to stem ration all are significantly affected by variation in duration of competition (Table 3). Crude protein (%) and total ash contents (%) were significantly reduced as the duration of competition extended from 4 WAE to full season competition but with minor fluctuation. Highest crude protein and ash contents were recorded in control treatment where no competition was allowed and in 4 WAE - full season treatments crude protein and ash contents decreased as the competition extended. Lowest contents of crude protein and ash contents were observed when full season competition was imposed during both the year of study. The reduction in crude protein contents in whole crop season competition was 4.80% and 10% in 1st and 2nd years (2013 and 2014), respectively than control treatment (parthenium free). Crude protein percentage was lower in 2014 as compared to 2013. The decline in ash contents in whole season crop competition periods was 1.5% and 8% over control (parthenium free) in 2013 and 2014, respectively (Table 3).

Discussion

Weed crop competition duration is the main factor which determines the growth and quality of crop. Weeds, due to their vigorous characters, influence over all traits of weeds and crop. Parthenium is a vigorously growing weed grown in different climatic range producing vigorous root system (Safdar *et al*. 2016). It is also reported that parthenium suppresses the growth of nearby plants by releasing allelochemicals (Singh *et al.* 2003; Belgeri and Adkins 2015). Increase in dry biomass of parthenium with extending competition duration from 4 weeks to full season in the study may be attributed to better growth advantage of parthenium over sorghum so a gradual increment in the dry biomass of parthenium was observed by extending its duration of competition with forage sorghum. Parthenium

Table 3: Influence of parthenium-sorghum competition durations on quality parameters of forage sorghum during two growing seasons

Competition durations	Crude protein (%)		Ash content (%)		Acid detergent fiber (%)		Neutral detergent fiber (%)		Leaf to stem ratio	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Control (Weed free)	9.99 a	8.90 a	15.43 a	14.55 a	34.56 c	34.87 c	53.65 c	51.66 d	0.379 a	0.38 a
4 WAE	9.95 a	8.62 ab	14.86 a	14.51 ab	35.03 bc	34.99 bc	54.21 bc	52.76 cd	0.355 b	0.37 ab
5 WAE	9.86 ab	8.45 ab	14.85 ab	14.46 bc	35.25 a-c	35.05 a-c	55.15 a-c	53.21b-d	0.313 c	0.35 a-c
6 WAE	9.72 bc	8.36 ab	14.64 bc	14.41 cd	35.71 ab	35.11 a-c	55.78 ab	54.18 abc	0.266 d	0.33 b-d
7 WAE	9.72 bc	8.24 ab	14.56 bc	14.39 cd	35.96 a	35.250 ab	55.95 ab	54.54 ab	0.227 e	0.31 cd
8 WAE	9.66 cd	8.11 b	14.35 bc	14.38 de	35.89 a	35.240 ab	56.62 a	54.66 ab	0.215ef	0.29 d
Full crop season	9.51 d	8.01 b	14.19 c	14.32 e	35.90 a	35.390 a	56.76 a	55.18 a	0.206 f	0.28 d
HSD value at 5%	0.172	0.665	0.65	0.07	0.72	0.35	2.09	1.64	0.01	0.05

The means following the same letters, within a column for each trait, did not significantly differ at 5% probability level
WAE= Weeks after crop emergence

being more competative than crop plant so accumulated more biomass as the competition extended from 4 WAE-full seasons. Vigorous root system of parthenium is responsible for uptake of more NPK at extended competition duration. As weeds are more vigorous in growth as compared to crop so parthenium uptake more nutrients when competition was prolonged. Several researchers reported that the increase in weed growth and NPK uptake by extending competition duration (Gaikwad and Pawar 2003; Maqbool *et al*. 2006; Anjum *et al*. 2007; Lindquist *et al*. 2007; Ikram *et al.* 2018). Moreover, the higher NPK uptake of parthenium during year 2014 compared to that observed in 2013 was attributed to its higher dry biomass due to more promising environmental conditions for its growth.

Increase in dry biomass accumulation of parthenium due to prolonge competition duration tended to decline in growth characteristics of forage sorghum (plant height, fresh fodder,leaf area, dry matter yields and stem diameter). Allelochemicals released by parthenium in soil during competition period may be the reason for decreased in growth and yield parameters of sorghum. Better competative ability of parthenium and accumulation of its more biomass was on the expense of reduction in growth of sorghum crop. Plant height, stem diameter, leaf area per plant were negatively affected due to weed crop competition for different resources and growth inhibiting factors released by parthenium (Bajwa *et al.* 2016). Reduction in growth traits of sorghum is more pronounced as competition extended (4 weeks - full season). These findings of research are similar with the reseach findings of Begna *et al.* (2001), Soliman and Gharib (2011). They reported that the decrease in plant height and stem diameter of maize with extending weed-crop competition duration in maize. Fresh fodder yield and dry matter yield is the comulative result of growth traits and highly dependent on the performance of these traits throught growing season in the presence of weed (James *et al*. 2000; Oljaca *et al.* 2007). Poor performance of yield contributing traits in the presence of weed was the reason for reduction in fresh fodder yield of sorghum whereas decline in sorghum dry matter yield in response to extension in duration of parthenium competition was probably due to fresh forage yield reduction. These reseach findings are supported by James *et al*. (2000) who observed that maize dry matter yield reduced significantly when weed plants were left uncontrolled. Extension in weed crop competition duration decreased the sorghum dry matter yield due to parthenium competition for nutrient with crop plants (Table 1).

Forage quality traits of sorghum such as crude protein, leaf to stem ratio and total ash contents of forage sorghum were reduced and NDF, ADF contents were increased due to prolong competition periods of parthenium in this study. The quality of forage sorghum spoiled due to decline in crude protein contents and ash contents as well as other quality attributes. The decline in crude protein and ash contents under parthenium competition stress may be attributed to reduced uptake of N by the crop during crop growth period as N is the main component of protein. Tanko *et al.* (2015) endorsed these results in his study on weed crop competition in lablab forage in Nigeria. Umar and Obukohwo (2013) reported reduced groundnut ash contents when extreme weed competition was present. Sorghum growth under stress and competing environment of weed crop competition reduced the digestibility of sorghum due to less leaf weight as compared to stem consequently ADF and NDF contents were increased and leaf to stem ratio reduced from 4-full season competition period. Massinga and Currie (2002) studied on corn and Temme *et al*. (1979) concluded that weeds presence reduced the forage digestibilty of alfalfa. Arabi and Saffari (2015) observed significant decline in leaf to stem ratio of sorghum crop when sorghum was kept infested with weeds throughout crop growing season. They also found the same results who observed a significant decrease in sorghum leaf to stem ratio under full season competition.

Conclusion

Parthenium may cause substantial yield and quality losses in forage sorghum and grow vigorously on the expense of sorghum growth. Reduction in yield and quality of sorghum increased when competition duration extended from 4 weeks after emergence to full season competition. Fresh forage yield losses varied 2.43–17.71% when competition was 4 weeks to full season along with quality losses as well. Therefore, parthenium should be controlled within 1st five weeks after the emergence of crop to avoid quality and yield losses of forage sorghum.

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