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Original article

# Interference of horse purslane (*Trianthema portulacastrum* L.) and other weeds affect yield of autumn planted maize (*Zea mays* L.)

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ABSTRACT

To assess comparative losses of *Trianthema portulacastrum* (HP) relative to other weeds, the experiment was set during consecutive summer seasons 2018 and 2019 at the Research Farm MNS-University of Agriculture, Multan, Pakistan. Experiment consisted three replications which were laid out under randomized complete block design. Experiment consisted of ten treatments viz: weeds free (whole season), HP free till 20 Days after emergence (DAE), HP free till 40 DAE, HP free till 60 DAE, all weeds free 20 DAE, all weeds free 40 DAE, all weeds free 60 DAE, weedy check (all weeds), weedy check except HP and weedy check containing only HP. During 2018 in all weeds weedy check, maximum HP relative density (33.33%) was observed while in 2019, plot where weeds were controlled from growing till 20 DAE showed (80%) relative density at 30 DAE. HP maximum frequency (66.67%, 77.78%) and relative frequency (66%, 100%) was recorded at 45 DAE in plots where HP was kept controlled till 20 DAE and all weeds kept controlled till 20 DAE, respectively. Maximum number of grains per cob (738, 700.68), 1000 grain weight (306.66, 271.51 g) and grain yield (6150, 8015 kg hec$^{-1}$) were recorded in plots which were kept all weed free till 60 DAE. As the competition period of weeds increased over 40 DAE, it substantially reduced yield of maize. Keeping the plots HP free till 40 DAE in the maize fields with HP as the major dominating weed, likely increase in maize grain yield is up to 30% compared to the fields where HP left un attended throughout the growing season. However, if maize field is infested with a mix of weeds with more than one dominating weeds including HP, compared to weedy situation the whole season, 30% higher grain yield can be obtained if all weeds are kept controlled till 40 DAE. Hence it can be concluded that whether the farmers face heavy HP infestation only or the mix of weeds as dominating weeds, in either case farmer should control weeds within first 40 days in maize field for better grain yield.

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## 1. Introduction

Weeds are unwanted plants in a given condition and may be detrimental for economics of field crop (Ekwealor et al., 2019) and reduction in yield (Baucom and Holt, 2009). All researchers agreed, weeds cause immense losses of food and its other commodities. Weeds in favorable conditions depending on type, have potential to reduce crop yield up to 60% (Yaduraju and Rao, 2013). Overall, in world, yield losses by weeds observed considerably (DAWN, 2003; Gharde et al., 2018). It cost 15% annual losses in agricultural production and cause 12 billion US dollar loss in crop production worldwide (DAWN, 2003).

Weeds are main limiting factor to attain a cost-effective production of crop. Weeds grow faster and quickly increase their population in a short period of time (Dangwal et al., 2010). Crop and weeds compete with each other by direct (interference) and indirect (allelopathic chemicals) ways (Zohaib et al., 2016). In field crop, weeds interfere with crop to obtain light, space, nutrient and water (Vollmann et al., 2010). In this interspecific competition, weeds use the essential resources, which will otherwise be used for main crop for growth and development (Zimdahl, 2007). This is considered as a major cause for growth and yield reduction in crops (Lindquist and Mortensen, 1999). Allelopathic chemicals restrict the crop growth and development of cereal crops (*Zea mays*) by producing phytotoxic chemicals (Bhatt et al., 2001). Crop growth and development mainly depends on weed crop competition period, as competition period prolonged, it adversely influenced growth and development of crop (Freitas et al., 2019). Durational interference of weeds significantly influences crop yield attributes as well as crop productivity (Yaghoobi and Siyami, 2008). Weeds have potential to reduce crop yield up to 1% per day (Kruger Seeds, 2018). It is basically depending on type of weeds. Noxiousness of weeds could be determined by competitive ability of weeds.

Out of over 30,000 weed species, 50–200 are more important to cause damage in field crops (Mahmood and Niaz, 1992) and can cause 11.5% grain yield loss in Pakistan (DAWN, 2003). The major weeds of summer crops are *Achyranthes aspera* (Prickly Chaff Flower), *Amaranthus retroflexus* (Redroot pigweed), *Convolvulus arvensis* (Field bindweed), *Cucumis melo* (Wild melon), *Sorghum halepense* (Johnson grass), *Cynodon dactylon* (Bermuda grass), *Cyperus rotundus* (Java grass) (Ullah et al., 2014) and *Trianthema portulacastrum* (Kaur and Aggarwal, 2017).

HP (horse purslane) is a very noxious annual herbaceous weed. It is considered as a one principle weed in various field crops, such as mustard, soybean, cotton and maize (Nayyar et al., 2001; Ray and Vijayachandran, 2013). It belongs to the Aizoaceae family. It originates from South Africa, but in recent era extensively observed in India, Sri Lanka and Pakistan (Saeed et al., 2010). HP (*T. portulacastrum*) solely showed equal competitiveness as the mixed stand of weeds in a soybean crop (Hazra et al., 2011). HP is a common weed of maize all over Pakistan (Hashim and Marwat, 2002) and can cause yield losses up to 25% (Gharde et al., 2018), 30% (Saeed, 2009) and 32% (Balyan and Bhan, 1989) in developed countries but it may have reached up to half of potential in under developed countries.

Hence, it is clear from the above discussion that weeds interfere with crop for resources and ultimately growth and development. To analyze the comparative damaging effect of weeds with HP (*T. portulacastrum*) on maize crop, an experiment was set in the field for two consecutive growing seasons in maize. Hypothetically it is considered that HP (*T. portulacastrum*) sole cause competitive losses compared to a mix of rest of the weeds in maize fields. However, the comparative influence of HP (*T. portulacastrum*) interference with other prevalent weeds on maize productivity is not extensively studied. Produced information related to comparative damage incurred by composite weeds and *T. portulacastrum* given us information about the extent of HP induced loss in maize grain productivity sole and as mixture which will help farmer to understand and subsequently plan the timing of managing HP sole or all weeds collectively as per the weed dynamics in maize fields to avoid economic losses.

## 2. Materials and methods

### 2.1. Experimental site

A study was set to determine the interference ability of HP relative to other weeds on weeds and maize crop yield at research area of MNS-University of Agriculture Multan, Pakistan during summer season of two consecutive years 2018 and 2019 under irrigated and arid conditions of Multan, Pakistan at (30° 12′ N, 71° 28′ E and altitude 123 m) on silt loam soil (Ali et al., 2009). District Multan has an average annual maximum temperature of 42 °C in June while minimum 21 °C in January (Weather and Climate, 2019).

### 2.2. Crop husbandry

A fine seedbed was prepared by three plowings and two planking to improve the soil moisture for better soil seed interaction. Maize variety DK-6714 (Monsanto Pakistan (Pvt.) Limited) was sown in 2nd week of July during both the growing seasons. The maize seeds were sown on beds through dibbling by using 25 kg $ha^{-1}$ seed rate with plants spaced at 15 cm apart and plant rows spaced at 75 cm. Net plot size was kept 3.0 m × 5.0 m. Fertilizer dose of N: P: K (200:125:125 kg $ha^{-1}$) was used in the form of Urea, DAP and SOP. Agronomic operations calendar during 2018 and 2019 in soybean field has been shown in Table 1. This study included ten treatments i.e weeds free (whole season), HP free till 20 Days after emergence (DAE), HP free till 40 DAE, HP free till 60

**Table 1**
Agronomic operations calendar during the studies in 2018 and 2019 in soybean field.

| Operations | 2018 | 2019 |
|---|---|---|
| Sowing date (2nd week of July) | 10 July | 13 July |
| Thinning | 23 July | 26 July |
| Irrigation | 17 July, 24 July, 02 Aug, 10 Aug, 20 Aug, 31Aug, 10 Sep, 21 Sep, | 20 July, 27 July, 04 Aug, 21 Aug., 01 Sep, 11 Sep., 23 Sep, |
| Fertilizer | | |
| Urea | 10 July and 25 July | 13 July and 28 July |
| DAP | 10 July | 13 July |
| SOP | 10 July | 13 July |
| Chemical control of Termite | 05 Aug, 12 Aug. | 30 July, 7 Aug |
| Weed density and biomass data recorded before harvest | 25 July, 09 Aug, 24 Aug, 08 Sep, 23 Sep | 28 July, 12 Aug, 27 Aug, 11 Sep, 26 Sep |
| Harvesting (2nd week of Oct.) | 13 Oct. | 15 Oct. |

DAE, all weeds free till 20 DAE, all weeds free till 40 DAE, all weeds free till 60 DAE, weedy check (all weeds), weedy check (except HP), weedy check (only HP).

### 2.3. Data collection

Data related to weed parameters were recorded i.e. density, dry matter, HP frequency %, HP relative frequency and HP relative density by using quadrate of 1 $m^{-2}$ at 15 days interval. Frequency percentage was determined by using the method used by Kilewa and Rashid (2014). While relative density and relative frequency was determined by using the equations of Yakubu et al. (2010) and Knox et al., (2011), respectively.

$$Frequency(\%) = \frac{Numberofsamplingunitsinwhichtargetedspecieoccured}{Sumofsamplingunits} \times 100$$

$$RelativeFrequency(\%) = \frac{Frequencyofaspecie}{SumofFrequencyofallspecie} \times 100$$

$$RelativeDensity(\%) = \frac{Densityofaparticularspecie}{Sumdensitiesofallspecies} \times 100$$

Parameters like plant height, number of grains per cob, 1000 grains weight, grain yield were recorded at the maturity of crop. Data related to parameters were statistically analyzed by Fisher's analysis of variance. HSD Tukey's test at 5 percent level of probability was used for the comparison of treatment means (Steel et al., 1997).

## 3. Results

The year effect was found significant for different parameters, hence the data has been presented and discussed here for both the years of study. The study site was infested with the purple nutsedge, HP, and wild cucurbits.

### 3.1. Frequency (%) of HP

At 30 DAE, during both the growing seasons, plots where HP was allowed to grow whole season, the frequency was 33.33% and 100%, respectively during both years (Fig. 2). Plots in which HP free condition was maintained till 20 DAE showed 66.67% and 77.77% frequency in 2018 and 2019, respectively. While the plots ensuring all weed free condition till 20 DAE showed 33.33%, 55.55% in 2018 and 2019, respectively.

The weedy check all weeds treatment recorded 33.33% frequency in both the years. At 45 DAE, whole season only HP employed treatment showed 66.00% and 100% frequency during both the years. Treatments where all weeds were managed till 20 DAE and weedy check all weeds allowed to compete with crop during whole growing season, showed 66.67% frequency in comparison to other weeds during both the growing years. In treatment (HP free till 20 DAE) HP frequency was recorded (66.67%, 77.77%). HP frequency percentage in plots where HP free condition was maintained till 40 DAE and all weeds free situation till 40 DAE recorded 33.33%.

### 3.2. Relative density of HP (%)

Data regarding the relative density of HP can be seen in the Fig. 3. At 30 DAE, in treatment where HP was not allowed to compete for 20 DAE, relative density of *T. portulacastrum* was (28.80%, 80.00%) in 2018 and 2019, respectively. In treatment all weeds free 20 DAE, relative density of *T. portulacastrum* was 25.00%, 63.33%, during 2018 and 2019, respectively. In plots where only HP was allowed to compete throughout the growing season with the maize plants, hence, its relative density was 100% during the whole season during both the years. At 45 DAE, it was observed that there was a decrease in relative density of HP as compared to 30 DAE as HP was approaching its reproduction stage. Data presented related to relative density (%) of HP in treatment (HP free 20 till DAE) was (24.20%, 49.85%) and in treatment (weedy check only HP) relative density was 100% as mentioned above in both the years. HP free till 40 DAE showed (15.38% and 5.67%) relative density during both the growing seasons. In treatment weedy check where all weeds were allowed to grow during whole growing season showed (30.01%, 37.14%) relative density during 2018 and 2019 growing years, respectively.

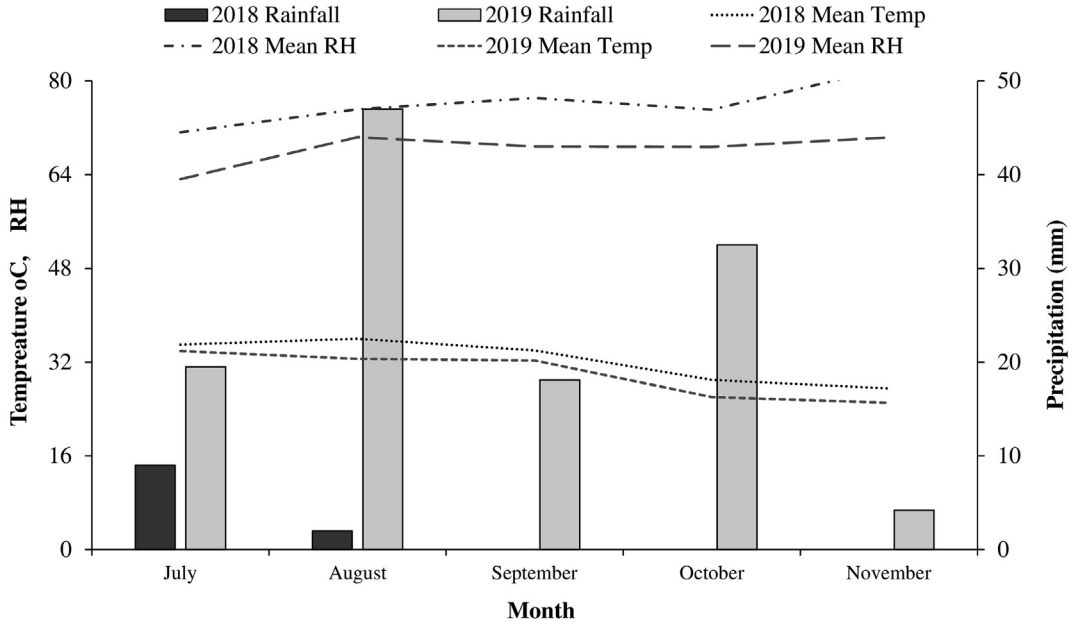
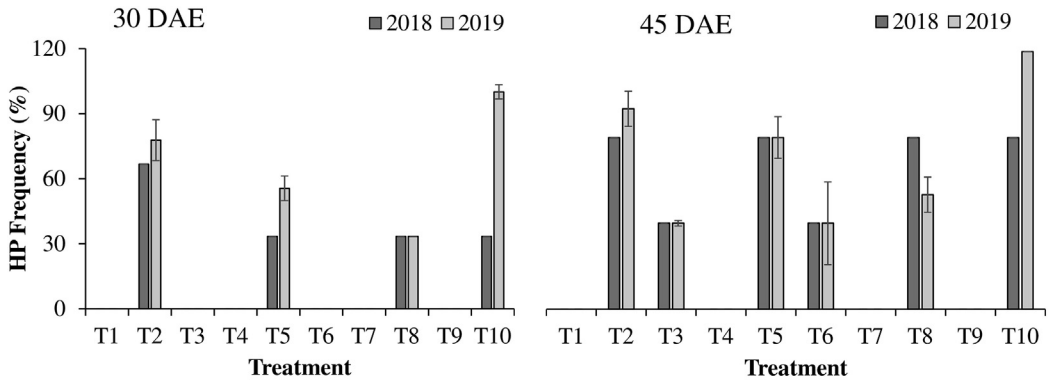
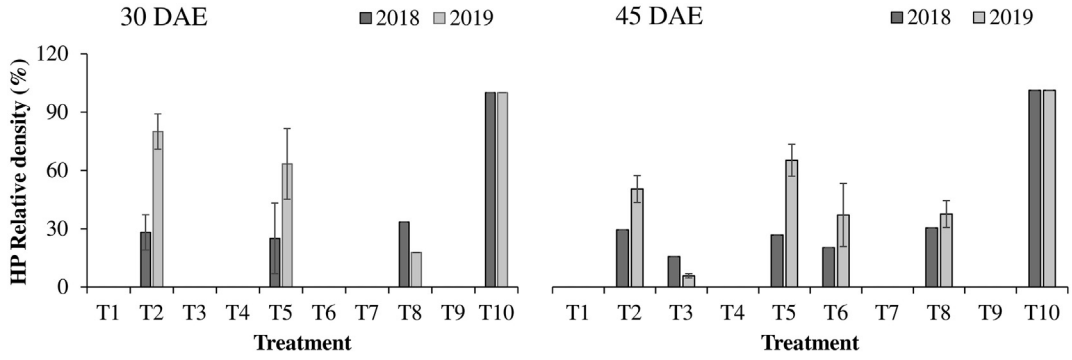



**Fig. 1.** Weather data during autumn season 2018 and 2019.




$T_1$: Weeds free (whole season), $T_2$: HP free till 20 Days after emergence (DAE), $T_3$: HP free till 40 DAE, $T_4$: HP free till 60 DAE, $T_5$: All weeds free till 20 DAE, $T_6$: All weeds free till 40 DAE, $T_7$: All weeds free till 60 DAE, $T_8$: Weedy check (all weeds), $T_9$: Weedy check (except HP), $T_{10}$: Weedy check (only HP)

**Fig. 2.** HP Frequency (%) as affected by weeds interference in autumn maize field at 30 and 45 DAE during growing season of 2018 and 2019.




T1: Weeds free (whole season), T2 : HP free till 20 Days after emergence (DAE), T3: HP free till 40 DAE, T4: HP free till 60 DAE, T5: All weeds free till 20 DAE, T6: All weeds free till 40 DAE, T7: All weeds free till 60 DAE, T8: Weedy check (all weeds), T9: Weedy check (except HP), T10: Weedy check (only HP)

**Fig. 3.** HP Relative density (%) as affected by weeds interference in autumn maize field at 30 and 45 DAE during growing season of 2018 and 2019.

### *3.3. Relative frequency of HP (%)*

During 2018 at 30 DAE, maximum relative frequency (%) of HP in treatment (weedy check only HP) could be attributed to the fact that as only HP was allowed to grow in this treatment so its relative frequency was 100% during the whole season (Fig. 4). Treatment (HP free 20 DAE) (all weeds free 20 DAE) and (weedy check all weeds) revealed 60.67% and 33.33%, respectively relative frequency of HP. During 2019, HP relative frequency (%) in treatment (HP free 20 DAE) was 78.77 (%). In treatment (all weeds free 20 DAE) it was 100%. In treatment (weedy check only HP) as only HP was allowed to grow in this treatment so its relative frequency was 100% during the whole season. During 2018 at 45 DAE, maximum relative frequency was observed (100%) in treatment where only HP was allowed to compete upon whole growing season as mentioned above. While treatment weedy check (all weeds) showed 66.67% and 44.45% relative frequency during both years respectively. Treatments HP free till 20 DAE and all weeds free till 20 DAE showed (66.67%, 77.78) and (66.67, 100%), respectively relative frequency during both years.

### *3.4. Density percentage of weeds at 30 DAE*

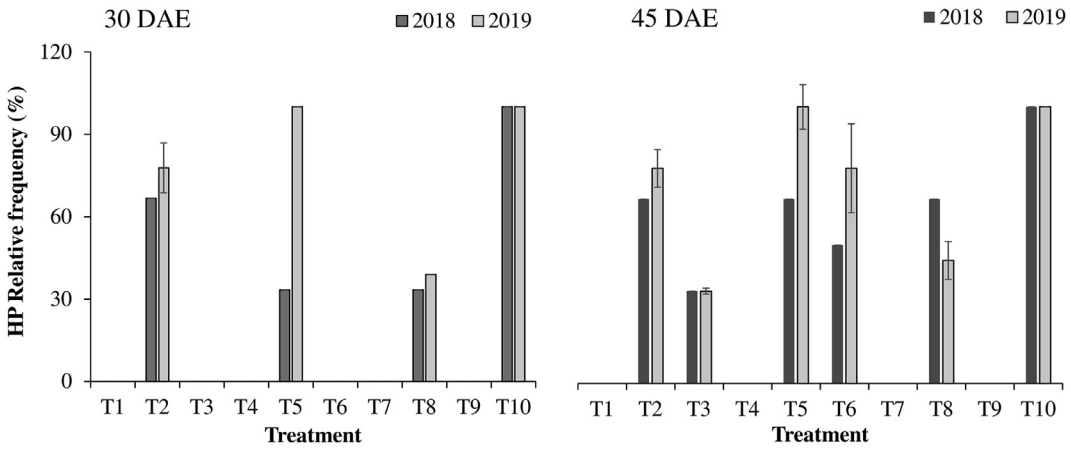
Presented data following pie graphs showed year factor of total dry matter to be significant. All weeds present in maize field at 30 DAE have been shown in Fig. 5. During 2018 growing season, HP was found 24 percent as compared to other weeds. While the purple nutsedge (*Cyperus rotundus*) was observed to be highest (39%) compared to other weeds. This infestation was followed by wild cucurbit (*Cucumis anguria*) at the infestation rate of 37%. In 2019, *C. rotundus* was observed highest (45%) whereas wild cucurbit (17%) was in lowest percentage. HP infestation was maximum 38% at this stage in the field.

### *3.5. Dry weight percentage of weeds at 30 DAE*

As HP is effective user of plant resources. During 2018 growing season, at 30 DAS total dry matter accumulated by weeds was determined in which HP recorded highest percentage. HP recorded 53% dry matter while *Cucumis anguria* showed lowest (10%). Next highest percentage of total weeds dry matter was 37% which was accumulated by *C. rotundus*. In 2019, highest (73%) dry matter in comparison to other weeds dry matter at 30 DAE was recorded by HP. Whereas, lowest (7%) was recorded by wild cucurbit. *C. rotundus* showed (20%) of total dry matter accumulated by weeds at 30 DAE.

### *3.6. Plant height (cm)*

During both the growing seasons of study, plant height was significantly influenced by treatments (Table. 2). Significantly maximum plant height (177.55 cm and 184.32 cm, respectively) was




T1: Weeds free (whole season), T2 : HP free till 20 Days after emergence (DAE), T3: HP free till 40 DAE, T4: HP free till 60 DAE, T5: All weeds free till 20 DAE, T6: All weeds free till 40 DAE, T7: All weeds free till 60 DAE, T8: Weedy check (all weeds), T9: Weedy check (except HP), T10: Weedy check (only HP)

**Fig. 4.** HP Relative frequency (%) as affected by weeds interference in autumn maize field at 30 and 45 DAE during growing season of 2018 and 2019.

observed during 2018 and 2019 in treatment (weed free whole growing season). Whereas, in weedy check treatment all weeds present whole growing season resulted in lowest plant height (125.95 cm) and (118.73 cm) during both the growing seasons, respectively. During first growing year, plots having all weeds free situation till 60 DAE showed plant height (172.52 cm) which was followed by the plot all weeds free maintained till 40 DAE having (168.83 cm) which was at par with treatments HP free till 40 DAE and HP free till 60 DAE. Treatment all weeds free till 60 DAE showed 172.52 cm plant height which was statistically at par with maize plots having all weeds free condition till 40 DAE. Whereas in 2019, plant height in HP free maintained plots till 40 DAE, was statistically at par with that of HP free for 60 DAS.

### 3.7. Number of grains cob$^{-1}$

The highest number of grains cob$^{-1}$ (765.19) and (771.33) respectively in both growing season were recorded in treatment weeds free whole season which was significantly highest as compared to all the other treatments (Table. 2). Next maximum number of grains cob$^{-1}$ (700.68) and (738.00) was observed in (all weeds free till 60 DAE) as plant nutrients and all other essential

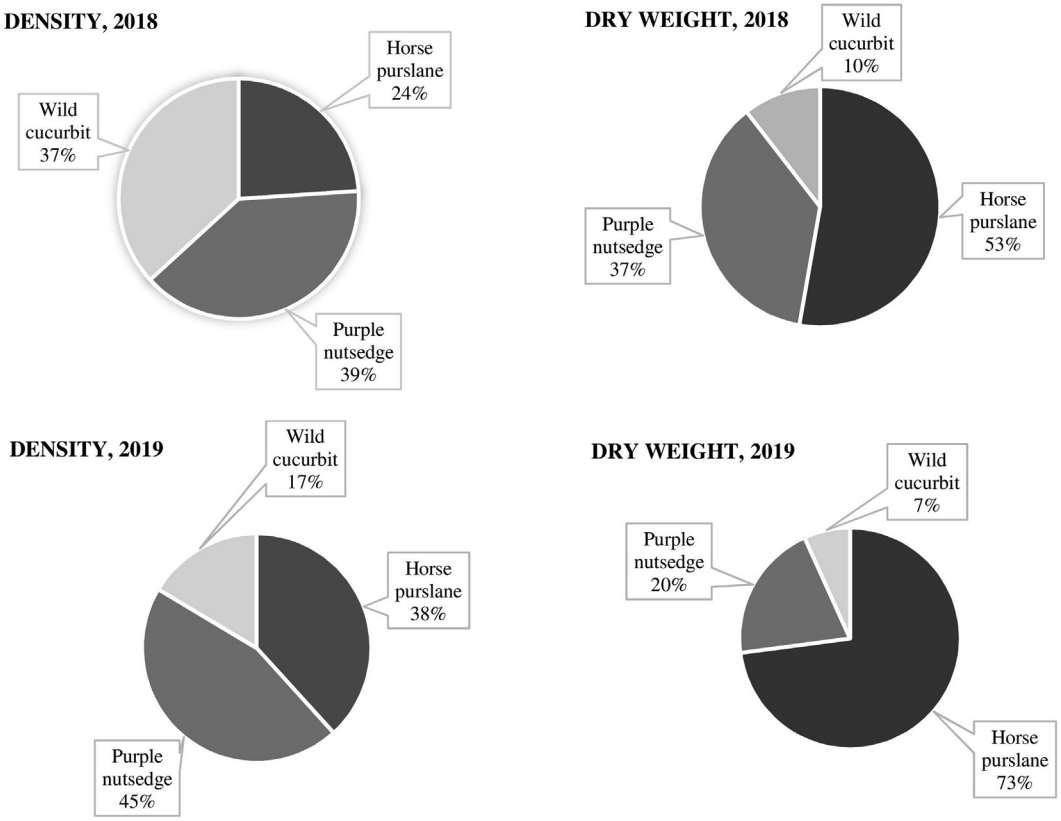



**Fig. 5.** Weeds infestation and dry weight percentage at 30 DAE during growing season of autumn maize 2018 and 2019.

**Table 2**
Effect of HP interference on plant height (cm), and yield related parameters of autumn maize during 2018 and 2019.

| Treatment | Plant Height (cm) | | Grains per cob | | 1000 grains weight (g) | |
|---|---|---|---|---|---|---|
| | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| Weed free (whole season free) | 177.55 a | 184.32 a | 765.19 a | 771.33 a | 310.66 a | 287.13 a |
| HP free till 20 DAE | 153.89 d | 159.20 d | 589.14 g | 549.33f | 286.00 e | 237.21f |
| HP free till 40 DAE | 168.19c | 167.32 cd | 642.92 e | 610.00 e | 292.64 cd | 243.37 e |
| HP free till 60 DAE | 168.53c | 169.36c | 662.39 d | 624.33 d | 298 .00c | 247.55 d |
| All weeds free till 20 DAE | 156.90 d | 149.40 e | 619.34f | 537.00 g | 288.66 de | 231.28 g |
| All weeds free till 40 DAE | 168.83 bc | 173.43 bc | 677.64c | 646.00c | 304.00b | 264.24c |
| All weeds free till 60 DAE | 172.52b | 178.51 ab | 700.68b | 738.00b | 306.66 ab | 271.51b |
| Weedy check (all weeds) | 125.95 g | 118.73 g | 446.38 j | 429.00 j | 262.55f | 198.88 j |
| Weedy check (except HP) | 134.06f | 129.56f | 492.52 i | 476.00 i | 264.55f | 218.81 i |
| Weedy check (only HP) | 140.07 e | 135.20f | 544.81 h | 518.00 h | 284.66 e | 224.18 h |
| HSD Tukey's value | 3.70 | 5.069 | 1.180 | 5.06 | 5.580 | 7.12 |

Means sharing same alphabet could not differ significantly at 5 percent probability level.

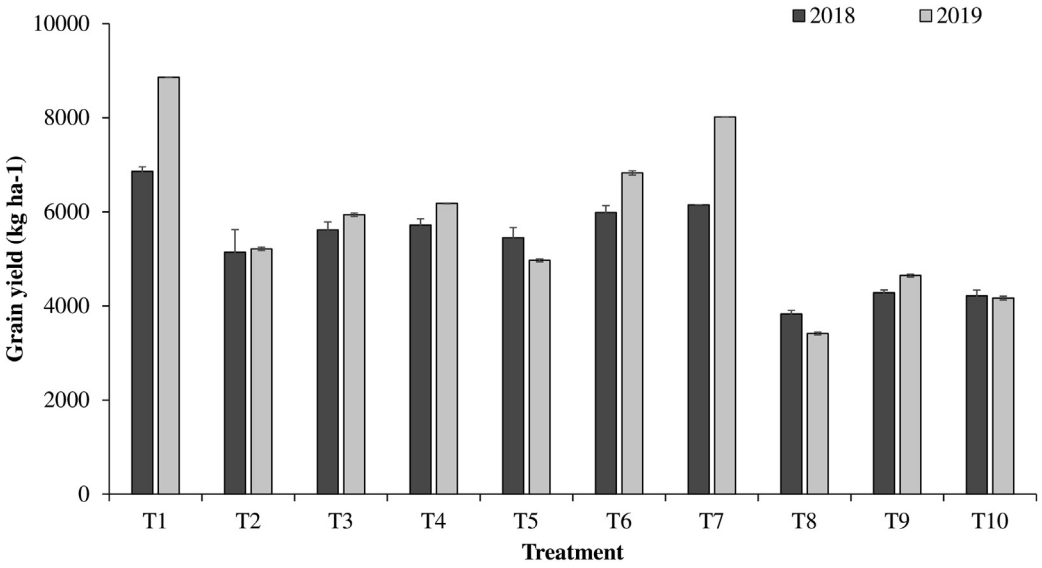
resources of plants were present in abundance. It produced more significant grain number than the treatment where plots were kept HP free till 60 DAE. During both the growing seasons, treatment (HP free till 60 DAE) resulted in 662.39 and 624.33, grains number in 2018 and 2019, respectively. It is evident of higher competitive ability of HP. Treatment all weeds free 40 DAE, enhanced weed crop interference period but still sufficient amount of water and nutrients were present which resulted in number of grains cob$^{-1}$ (677.64 and 646.00) during the consecutive years, respectively. In treatment, HP free 40 DAE, however other weeds were allowed to grow which competed with maize plants had number of grains cob$^{-1}$ 642.92 and 610.00, respectively in two consecutive years. HP free till 20 DAS showed significant low level of number of grains per cob (589.14) during first growing season over composite weeds competition till 20 DAS (619.34). Whereas in both the years, treatment weedy check all weeds, where all weeds were allowed to grow whole growing season resulted in lowest grain number per cob of 446.38 and 429.00 in year 2018 and 2019, respectively.

### 3.8. 1000 Grain weight (g)

Presented data (Table. 2) showed that thousand grain weight of maize was significantly influenced by weeds density during both the growing seasons i.e. 2018 and 2019. Heaviest thousand grain weight (310.66 g, 287.13 g) was recorded in whole season free treatment during 2018 and 2019. 1000 grain weight could not vary significantly with all weed free situation maintained plots in 2018 growing season. However, for the same two treatments in 2019 brought significant variation. The lightest thousand grains weighed from weedy check all weeds plots (262.55, 198.88 g) during 2018 and 2019, respectively. Treatment HP free till 40 DAS showed (292.64, 243.37 g) while treatment all weed free till 40 DAS showed (304.00, 264.24 g) during both the growing seasons, respectively.

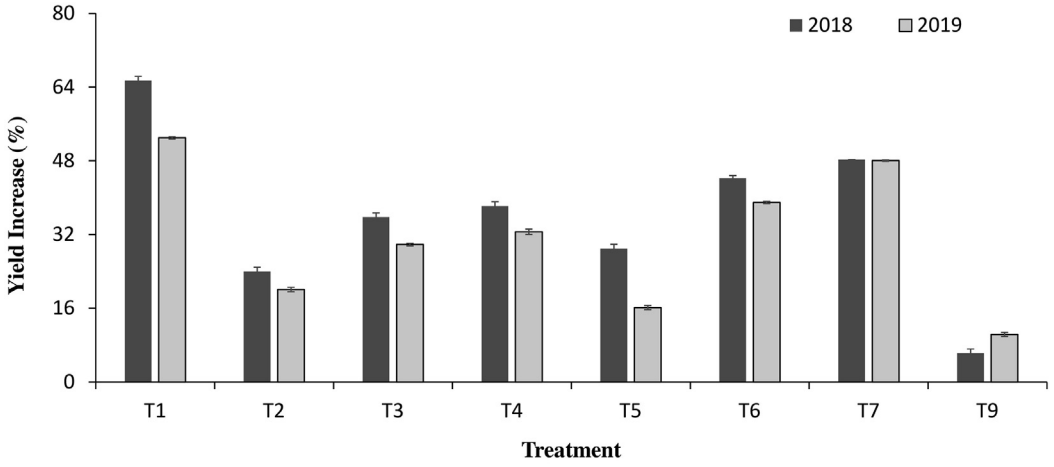
### 3.9. Grain yield (kg ha$^{-1}$)

Presented data showed in Fig. 6 revealed that maximum grain yield (6860, 8859 kg ha$^{-1}$) was observed in the plots where during both the growing seasons weed competition free environment was provided to maize plants. Statistically next maximum grain yield (6150, 8015 kg ha$^{-1}$) was observed in treatment where, plot was free from all weeds till 60 DAE. It provided favorable environmental conditions for growth and development of crop. Whereas, the lowest grain yield (3826, 3413 kg ha$^{-1}$) was recorded in weedy check treatment where all weeds were present during whole growing season.




T1: Weeds free (whole season), T2: HP free till 20 Days after emergence (DAE), T3: HP free till 40 DAE, T4: HP free till 60 DAE, T5: All weeds free till 20 DAE, T6: All weeds free till 40 DAE, T7: All weeds free till 60 DAE, T8: Weedy check (all weeds), T9: Weedy check (except HP), T10: Weedy check (only HP)

**Fig. 6.** Effect of HP and other weeds interference on grain yield (kg ha$^{-1}$) of autumn maize during 2018 and 2019.




T1: Weeds free (whole season), T2: HP free till 20 Days after emergence (DAE), T3: HP free till 40 DAE, T4: HP free till 60 DAE, T5: All weeds free till 20 DAE, T6: All weeds free till 40 DAE, T7: All weeds free till 60 DAE, T8: Weedy check (all weeds), T9: Weedy check (except HP), T10: Weedy check (only HP)

**Fig. 7.** Percent yield increase in autumn maize over weedy check (only HP) as affected by HP and other weeds interference during 2018 and 2019.

### *3.10. Yield increase percentage over weedy check (only HP)*

Data showed that as compared to weedy check treatment (only HP) during both the growing seasons, 2018 and 2019 grain yield obtained in weed free (no weeds during whole growing season) was 65.38% and 53% higher, respectively (Fig. 7). Grain yield obtained in weeds free till 60 DAE over weedy check (only HP) was 48.24% and 48.02%, respectively during the consecutive seasons. Maize plants in plots with all weeds free condition till 40 DAE, produced grain yield which was 44.23% and 38.98% higher over weedy check only HP treatment in 2018 and 2019, respectively. Grain yield in treatment where HP was controlled till 60 DAE resulted in 38.19% and 32.60% higher yield than weedy check (only HP), respectively during both the years. Plot HP free till 40 DAE showed 35.77% higher yield than weedy check (only HP). HP free till 20 DAE treatment employed plots revealed 23.97% and 20.06% higher grain yield during consecutive years, while all weeds free till 20 DAE exhibited 34.32% higher yield than weedy check treatment. But as compared to grain yield in treatment (weedy check only HP) the grain yield in treatment (all weeds free 20 DAE) was 28.94% and 16.13% higher during the consecutive years of the study. Weedy check (except HP) showed 6.22% and 10.31% higher grain yield respectively during both the years. It reflects that in plots where weedy check only HP treatment was imposed, HP growth was most aggressive and had reducing effect on the crop growth and yield. As compared to plots kept weedy for all weeds, grains yield obtained from weedy check (only HP) treatment was 8.37% and 18% greater during both the years, respectively.

## 4. Discussion

Frequency (%) is defined as "ratio among total number of quadrates (sampling units) in which targeted specie occurred and total number of quadrates. By using the frequency percentage data, we can conclude the distribution in terms of the frequency percentage. In presented data, it was pertinent to note that the HP frequency percentage was higher compared with other weeds in the corresponding growing seasons. This could be attributed to the favorable environmental and edaphic conditions. Due to presence of most favorable environmental and edaphic conditions HP frequency (%) could have dominated the experimental site. Mean population frequency percentage of weed in favorable conditions was up to 96% (Kilewa and Rashid, 2012). It of course depicts the heavy weed seed infestation in the same field of trial. Relative density (%) indicate the strength of a particular species in comparison to the sum of individuals of all species occurred in a specific field. HP relative density (%) was maximum on 30 DAE during both the growing years. This revealed that at 30 DAE HP was dominant over sum of other weeds found in that period in various treatments. This data revealed the dominance period of HP as compared to other weeds in this study area. Relative frequency indicates the degree of dominance of a particular weed over all the other weeds present in an area at the certain period of time. HP relative frequency was maximum at 45 DAE, which could be due to the presence of favorable conditions for its growth and development. It is evident from the data that HP is very aggressive when found favorable conditions as compared to all other weeds. This clearly indicate that growth of HP suppressed the other weeds which were present in the area and gained competitive advantage for essential plant resources over other prevalent weeds. This attributed to the competitive ability of HP to catch plant resources more efficiently. Higher relative density could be attributed to environmental condition which supported the HP to prolong the growth and development during 2019, particularly in all weeds free till 20 DAE. HP completed lifecycle at 90 DAE during this study. Presented data can help us to understand the ability of HP to utilize the available plant resources with respect to weeds and cultivated plants. It also helps us to determine the critical period of HP by observing at what duration it grows aggressively in the maize crop and should be kept free from HP to attain profitable yield. Mean relative density of broad leave weeds was 62% in crop fields (Yakubu et al., 2010).

It was noteworthy that though HP relative density was found higher at 30 DAE. However, frequency % and relative frequency % was observed maximum at 45 DAE. It suggests that at 30 DAE overall % age of HP infestation was higher relative to other prevalent weeds. Whereas, the distribution and spread of HP over the test field of maize was more uniform at 45 DAE. It suggests that after the first 20 DAE the HP emergence and early growth was favored more in 25 days when compared with other weeds like purple nut sedge and wild cucurbits. Hence higher relative frequency of HP was evident. It is also conclusive from the same results that from 20 DAE to 45 DAE the relative aggressiveness of HP was observed to be higher than purple nut sedge and wild cucurbit (Ara et al., 2015).

During both growing years HP stood on 2nd number while in total dry matter production it accumulated highest total dry matter. Over the year its infestation 66% also increases in 2019 as compared to 2018. Here we can conclude that HP was most aggressive at 4–5 weeks after emergence as compared to all other weeds present in the study area. It also showed that HP growth was almost 50 percent whereas growth and development of all the other weeds were lower than HP so it's important to control HP more effectively as early as possible to eliminate the competition for nutrient and all other resources and to avoid yield losses till 45 DAE (in autumn sown crop till end of august). These findings were comparable with Ugalechumi et al. (2018) who stated that significant number of HP can restrict the growth of crop. As weeds found favorable conditions it can produce more biomass than crop (Jeschke et al., 2009). Overall, weeds infestation was higher at 30 DAE during both growing years. However, during 2019 growing season. Climatic attributes like rainfall, RH etc. were higher (Fig. 1). This could have resulted in more growth of weeds particularly annual weeds especially HP. Higher HP relative density % frequency % and relative frequency % in 2019 is evident from Figs. 2 to 4. Furthermore, it was noteworthy that purple nut sedge seed bank was the highest in the study soil. HP ranked 2nd higher among infestation in maize field under study. However, when accounting for dry matter damage by individual weed, it was found that during both season HP dry weight exceeded far ahead of purple nut sedge and other prevalent weed. It reflects the response of use efficiency and uptake potential of HP over other weeds. Higher uptake and resource use efficiency over purple nut sedge is understandable owing to annual nature of HP while purple nut sedge have steady growth over year due to perennial nature. Hence resource use efficiency of purple nut sedge over HP is reasonably lower (Ara et al., 2015).

Year effect was significant hence the yield related data has been presented and discussed separately. Higher plant height in whole season free plot could be owing to lack of interference for crop resources. Maize plant used available resources and nutrients effectively which helped the plant to grow better. Whereas, in weedy check treatment all weeds present whole growing season increase the interference period resulted in lowest plant height during both the growing seasons. Plots where only HP was allowed to grow resulted in evident reduction in plant height through aggressive resource uptake by HP. Two HP flushes over the growing season could have kept maize plants continuously under stress thereby expressing the lower plants at harvest. These results are similar to the findings of Azhar (2009), who stated that an increase in maize plant height was due to the better suppression of weeds which resulted in reduced competition with maize for growth factors.

Maximum number of grains $cob^{-1}$ were recorded having minimal interference (whole season free plot) caused by weeds. Overall during both the years, as interference period increased, significant low number of grains were observed. It was interesting to note that sole HP interference with maize plants resulted in reduced grains $cob^{-1}$ when compared with composite weeds interference. Presented data supported by the findings of Tanveer et al. (1999) who reported that interference period significantly influences number of grains $cob^{-1}$.

Substantial low 1000-grain weight was in plot where higher competition was observed by HP and composite weeds to interfere in utilization of plant resources. Presented data also showed that weed crop competition period put a significant influence on crop growth processes that influenced the development of crop. As interference period prolonged, it influenced yield attributes substantially. This is the reason that weed free crop stand resulted robust 1000 grains weight as well as crop yield. It was interesting to note that, across the year's taller plants with more number of grains formed in 2019 however the heavier grains with more dry matter accumulation and photosynthates accumulation was observed in 2018. It could be attributed to reduced dilution effect for grain weight. The taller plants and more grains per cob could have resulted from more intra specific competition and dilution effect respectively. Subsequently resulting in reduced photosynthates accumulation in grains, hence reflecting lighter grains per 1000 grains in 2019. The 1000 grains weight ultimately grain yield significantly reduced with the increase in the competition among crop and weeds (Narkhede et al., 2000; Tomar et al., 2003).

Maximum grain yield attributed to the plots where no competition among crop and weeds was allowed during whole the growing seasons. So this luxuriant environment resulted in uptake of maximum plant resources by the crop plants only. Grain yield in all weeds free plots till 40 DAE exhibited higher output than the plots which were free from HP till 60 DAE. However, the treatment with all weeds competition till 40 DAE and the similar competition period solely by HP showed significant reduction in grains yield. This revealed the significance to manage composite weeds including HP at early crop growth stages to obtain better maize crop productivity. These results also showed HP ability to compete with crop for resources which was more than composite weeds. HP solely reduce more grain yield compared to all weeds. However, in treatment all weeds free till 20 DAE showed more damage to maize grain yield than treatment where only HP was controlled till 20 DAE. However, treatment all weeds free till 20 DAE showed (33.15%, 63.33%) HP relative density, respectively during both the years. More reduction in grain yield in composite weed free situation till 20 DAE could be attributed to the fact that besides higher relative density of HP, other weeds infesting the maize fields till 20 DAE would have also contributed additively to reduce maize grain yield. Minimum maize grain yield was observed due to the uncontrolled weeds growth and development most importantly during the critical growth stages of maize crop. To attain higher grain yield in maize crop, the competition period among weeds and crop should be minimal (Narkhede et al., 2000; Tomar et al., 2003; Takim, 2012).

Comparison among weedy check (only HP) and rest of treatments were employed to check the % increase of yield in all treatments over weedy check (only HP). In plots where weedy check only HP condition was imposed, HP was allowed to grow while rest of the weeds were controlled manually. Rest of the treatments were also maintained according to the treatments nature. In treatment where weeds were controlled whole season, crop used all plant resources efficiently resulting in maize optimum growth and development. Next maximum yield increase % over weedy check was recorded in all weeds free 60 DAE, where weeds were managed for most of the early crop growing season which was the critical weed control duration. In treatment, with all weeds free till 40 DAE condition employed, weed competition period was increased as compared to all weeds free till 60 DAE and weeds utilized the crop available resources effectively. Resource uptake was in favor of the weeds at this stage. At critical crop growth stage limited resource availability affected the grain yield of maize plants in treatment where all weeds free till 40 DAE was maintained. As competition period increase by weeds from 60 DAE to 40 DAE, percentage of yield increase substantially.

In plots where HP was kept from growing till 40 DAE, other weeds kept growing and due to presence of other weeds the reduction in grain yield is obvious when compared with all weeds free till 40 DAE. In treatment all weeds free 20 DAE, all the weeds were controlled during the early crop growth days till 20 DAE, as all weeds were allowed for the entire season afterwards. This increase in weed crop competition, increased HP interference and uncontrolled growth, development of different weeds affected the grain yield. Higher yield losses of 29.5% and 30.2% were observed in

treatment having higher weed population of 18 plants per meter square in maize crop (Saeed et al., 2010). Higher rainfall during July-August in 2019 would have favored robust HP growth than the other prevailing weeds in the field like purple nutsedge, wild cucurbits (Ara et al., 2015).

Overall in plant height, grain yield and yield attributes it was notice that plots where all weeds were kept from growing till 60 DAE showed improve growth and yield and yield attributes as compared to plot where all other weeds except HP was allowed to grow. It is again evident of the importance of HP in the field interfering with maize plant. It was noteworthy that photosynthesis and dry matter accumulation and partitioning was reduced in 2019 growing season results in lighter grain. It could be related with climatic conditions including higher rainfall resulted in more HP frequency %, Relative density and Relative frequency % (Figs. 2-4).

Reduced HP frequency, relative density and relative frequency could have exhibited higher grain yield in plots where all weeds free situation was ensured till 60 DAE over weedy check only HP. Furthermore, the grain number per cob and heavier 1000 grain weight could have resulted in more grain yield in plots ensured all weeds free for 60 DAE. The overall increase in grain yield over HP weedy check was more in 2018 than in 2019. It is quite understandable due to the higher HP infestation and dry matter manage in 2019 owing to more favorable rainfall, relative humidity and temperature etc. Moreover, the better soil moisture situation in 2nd growing season would have stimulated HP emergence over first year growing season. If maize field infested with composite weeds and kept free till 40 DAE and 60 DAE showed (30%) and (36%), respectively higher yield than plot infested with weeds during whole season. The rise in yield from 40 DAE to 60 DAE is merely 6%. To ensure 20 days more weed free situation, the expenses needed for weed control will increase than the yield increase benefit and will not be economical.

HP though a very aggressive weed could not prove to be the more dominant in terms of reducing grain yield in autumn maize fields when compared with all other weeds in integration (purple nut sedge, wild cucurbit etc) infesting the maize fields. Though the dry matter of HP was higher than the other weeds in maize fields, the density was lower than purple nut sedge. Moreover, it was interesting to note that HP damage is more evident when infesting maize field in combination with other prevalent weeds. HP interference and aggressiveness is further stimulated in synergism with perennial weed like purple nut sedge and annual weed like wild cucurbit.

## 5. Conclusion

If maize plots are kept HP free till 40 DAE, maize grain yield can be increased up to 30% as compared to the imposition of whole season competition by HP. It can be concluded that in the field having weeds heavy infestation history particularly HP, maize growers besides controlling other weeds should keep an eye on HP and control HP till 40 DAE not only to minimize its interference damages but also to improve the maize grain yield. However, the higher grain yield can be obtained by managing all weeds free situation till 40 DAE. Managing only a single weed like HP in the maize field infested with other weeds too, is neither feasible nor economical. Hence the farmers should control all weeds including HP well within 40 DAE to reduce the weeds interference and to obtain improved maize grain yield.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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