

WEED MANAGEMENT AND YIELD IMPROVEMENT IN MUNGBEAN THROUGH ALLELOPATHIC ACTION OF SUNFLOWER AND BERMUDA GRASS EXTRACTS IN CONJUNCTION WITH IRRIGATION FREQUENCIES

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Abstract

A field study was conducted to evaluate the allelopathic potential of sunflower (*Helianthus annuus* L.) and bermuda grass (*Cynodon dactylon* L.) extracts under various irrigation levels on weed density and yield of mungbean cultivar AEM-96. The experiment consisted of different weed control practices i.e. weedy check, various levels of sunflower / bermuda grass extracts, herbicides and hand weeding under three irrigation frequencies (2, 3 and 4). The analysis variance showed that various weed control practices caused significant suppression of weeds and increased seed yield as compared to weedy check. The application of sunflower extract @ 15 L ha⁻¹ in combination with herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) resulted in minimum weed parameters viz. density (52.0 m⁻²) and dry weight (99.0 g m⁻²) and produced maximum mungbean growth and yield traits particularly seed yield (2404 kg ha⁻¹). Bermuda grass extract @ 15 L ha⁻¹ in integration with herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) followed in effectiveness with weed density of 61.0 m⁻² and weed dry weight of 132.0 g m⁻² as well as mungbean seed yield of 2282 kg ha⁻¹. As much as irrigation frequencies are concerned, the least weed density (82.0 m⁻²) was recorded in two irrigations but optimal seed yield (1965 kg ha⁻¹) of mungbean was noted in three irrigations. Hence, the results suggested that combination of plants extracts and herbicides at reduced doses controlled weeds efficiently and optimum enhancement in seed yield of mungbean was noticed at three irrigations.

Keywords: Allelopathy, bermuda grass, seed yield, sunflower, weeds

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Introduction

Mungbean (*Vigna radiata* L.) is an essential pulse crop worldwide including Pakistan (Arain, 2012). Mungbean seeds are mostly rich in protein, which contain about 20.97–31.32% protein (Anwar et al., 2007). Mungbean seed contains protein double than cereals (Chen et al., 2014) and significantly higher protein content than observed for conventional root crops (Kudre et al., 2013). It is cooked, processed, roasted, sprouted or grinded and it is also most essential pulses grown for edible seed. It is a source of high-quality protein for human consumption and can serve as a multipurpose crop, if harvest residues are used as fodder or green manure (Pataczek et al., 2018). It is annually cultivated on an area of 162.4 thousands ha with total production of 122.0 thousands tones in the country (GoP, 2018).

Weeds are considered as the most harmful to agricultural production among biotic constraints. Weeds also indirectly influence the crop production through competing with crop in resources, sheltering crop pests, interfering in water management, reduced yield and quality, and subsequently raising the price of processing (Zimdahl, 2013). Weeds interfere with crop plants not only through competition but also with allelopathy (Javaid et al., 2007; Kandhro et al., 2016). Gharde et al. (2018) reported actual yield losses of 13–43% in mungbean due to weeds whereas Mirjha et al. (2013) noticed it as ranging from 30–85%. The losses in yield of mungbean and other crops depend upon weed species, their densities and crop weed competition period (Siddiqui et al., 2010). Sharma and Singh (2011) claimed that competition of weeds and crops for water, nutrients and other growth traits, and in lack of an effective weed reducing measures, weeds remove large quantity of applied nutrients resulting in more loss in yield and conditions become severe under its insufficiency. Therefore, it is necessary to discover new weed control methods, which should be natural, environment

friendly and effective. Allelopathy is one of the environment friendly and cheapest approaches for weeds supervision (Iqbal and Cheema, 2009; Shafiq et al., 2013). Many recent studies have shown that noxious weeds such as parthenium can be controlled by using extracts of allelopathic weeds namely *Ageratum conyzoides* and *Coronopus didymus* (Javaid et al., 2020; Javaid and Khan, 2020). Sunflower (*Helianthus annuus* L.) has been largely studied due to allelopathic nature (Kamal, 2011) and sustainable weed reduction approach (Javaid et al., 2006; Jabran et al., 2015). Sunflower being an important allelopathic crop releases glycosides, sorgoleone, alkaloids, phenolics, flavonoids and terpenoids allelopathic compounds that actively reduced the growth of near plant species due to highly allelopathic nature (Anjum and Bajwa, 2008), and they affect germination of seeds (Hozayn et al., 2011). Weed density and biomass is reduced significantly by using allopathic crops and weeds (Cheema and Khaliq, 2000; Javaid et al., 2010, 2011). Allelopathy has been effectively utilized to control weeds in various crops including mungbean fields. The yield increased from 15 to 25% by controlling weeds through allelopathic plant extract (Cheema et al., 2013).

The Bermuda grass plant material contains allelopathic compounds with phytotoxic efficacy. The many water soluble allelopathic compounds such as caffeic acids, phenolic acid, vanillic, ferulic and p-cumaric are released by this weed. The crop growth and yield may be affected by availability of this weed in field. Furthermore, allelopathic material of bermuda grass could be used to reduce weeds under field environment (Kandhro et al., 2015). Bermuda grass extract had powerful allelopathic and inhibitory effects on various characters of basil and common purslane. Mahmoodzadeh and Mahmoodzadeh (2014) exposed that all Labiatae species seed germination was completely reduced by applications more than 2% rhizome bermuda grass extract. The extract had powerful reduction effect on root expanded of seedling in legumes

and Labiatae to shoot expanded in Poaceae. Bermuda grass rhizomes may be a source for bio-herbicide against sorghum halepense which will assist to reduced invasive plants. The effects of this study support the observation of Yarnia *et al.* (2010) who described that crop growth significantly reduced by bermuda grass material releases allelopathic chemical.

Sufficient water must be used timely to achieve more grain yield under irrigated areas. So, water use of plant and periods is fundamental to conclude that flora is vulnerable for water nearby watering application periods to enhance yield in a sufficient area. It is most essential pulses have noticeable wetness responsive step of development in relation to grain yield. During pod and seed formation, the moisture applied is very essential. Weed density and dry weight were considerably influenced by the quantity of water applications in all the mulching, hand weeding and weedy plots (Towa and Xiangping, 2014). Mahbod *et al.* (2009) stated that the yield improved significantly by increase in water application levels from three to six and appropriate weed-reduction procedures can improve the effectiveness of utilization of water in crop. Nadeem *et al.* (2014) reported weed population and dry weight increased with increase in water application levels. Proper water management is the most important factor in controlling weeds during crop production as well as hand weeding.

MATERIALS AND METHODS

To examine the weed inhibition and yield enhancement in mungbean through allelopathic action of sunflower and bermuda grass extract in conjunction with irrigation frequencies, the study was carried out at Sindh Agriculture University Tandojam, Pakistan in spring seasons of 2019 & 2020. The design of experiment was split plot design having factorial arrangements with four replications. The area of treatment units was 4 m × 4 m (16 m²). The texture of soil appeared silty clay loam, with limited nitrogen (0.021%), low organic matter (0.42%) and high in

pH (8.24). The experiment consisted of Two Factors. The main-plot comprised of 3 irrigation regimes (2, 3 & 4 irrigations) and Sub-plot consisted of weed control practices (weedy check-untreated, sunflower extract @ 30 L ha⁻¹, bermuda grass extract @ 30 L ha⁻¹, sunflower + bermuda grass extract each @ 15 L ha⁻¹, hand weeding @ 30 days after sowing, atlantis @ 0.2 L ha⁻¹ + puma super @ 0.312 L ha⁻¹, sunflower extract: @15 L ha⁻¹ + atlantis: 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹, bermuda grass extract @ 15 L ha⁻¹ + atlantis: 0.1 L ha⁻¹+puma super @ 0.156 L ha⁻¹). The extracts and herbicides were applied as per respective treatment after first irrigation. The seeds of mungbean were sown on drilling method in respective plots by single coulter hand drill. Nitrogen and phosphorus were applied at recommended dose of 25-50 kg ha⁻¹ in urea form and DAP. Total DAP and 1/2 Urea were used during land preparation and remaining Urea was used at the time of 2nd irrigation. The crop earthing-up was exercised 2 times after 1st watering and second after 2nd watering application.

Measurement and observations

Weed and Crop collection data

Weed density (m⁻²): Weeds were counted at 60 DAS. A wooden frame of one meter square was utilized to note total number of weeds per meter square.

Weed density (m⁻²) = Total No. of weeds (m⁻²) for given treatment /No. of replications

Weed dry weight (g m⁻²): The weed dry weight was collected from 3 locations of every unit. Weeds were harvested at floor level and dried up through oven for 48 hours at 70 °C to note dry weed weight.

Seed germination (m⁻²): Ten days after sowing, seed germination per square meter was collected by counting the seedlings of mungbean.

Leaf area index: The data of leaf area index was noted from selected 5 plants when crop was in peak vegetative growth by the formula:

$$\text{Leaf area index} = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Ground area per plant (cm}^2\text{)}}$$

Pods plant⁻¹: Pods per plant were counted from selected five plants in every plot and average was recorded at maturity.

Seed weight pod⁻¹ (g): The collected seeds of five randomly chosen pods were weighed individually and the weight of grains per pod average was recorded in grams.

Biological yield (kg ha⁻¹): Data of crop biological yield was noted as per following formula:

$$\text{Biological yield} = \frac{\text{Crop biological yield per plot (kg)}}{\text{Area per plot (m}^2\text{)}} \times 1000$$

Seed yield (kg ha⁻¹): Data regarding seed yield of mungbean was noted from harvested plants for crop biological yield by using the formula:

$$\text{Seed yield} = \frac{\text{Seed yield per plot (kg)}}{\text{Area per plot (m}^2\text{)}} \times 1000.$$

Statistical analysis

The data was statistically analyzed following ANOVA technique using software Statistix version 8.1 (Statistix, 2006). The least significant difference (LSD) test was used at alpha 0.05 for comparing differences of treatments.

Meteorological data

During experimental season the meteorological data of Tandojam of 2 years (2019 and 2020) were collected from Meteorological Observatory Station, DRIP, Tandojam. The information of meteorological data on monthly basis for February, March, April and May regarding standard temperature (°C), Rainfall (mm) and humidity (%) are mentioned in Fig.1

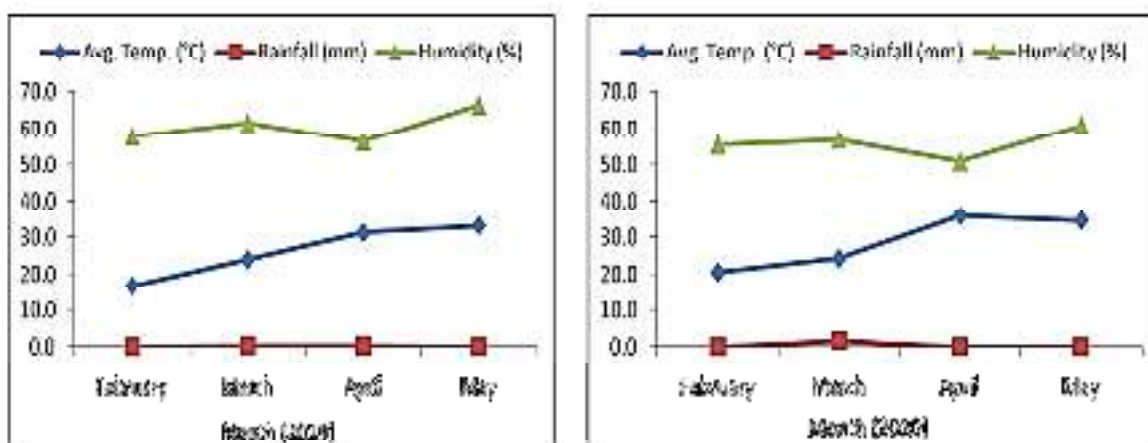


Fig. 1. Meteorological data of Tandojam during crop season (2019 and 2020)

RESULT AND DISCUSSIONS

Weed density (m⁻²)

The weed density (m⁻²) of mungbean differed significantly under study (Table 1). Combination of sunflower extract @ 15 L ha⁻¹ + herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) resulted in lowest (52 m⁻²) weed density followed by integration of bermuda grass extract @ 15 L ha⁻¹ + herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) with weed density of 61 m⁻² whereas highest (141 m⁻²) weed density was noted in weedy check (untreated). Irrigation frequencies also significantly affected the weed density. Two irrigations (30 and 60 DAS) gave

lesser weed density (81 m⁻²) as compared to three and four irrigations (85 and 88 weed density m⁻²). Significant effects for interaction of weed control practices × irrigation frequencies were also observed for weed density. Sunflower releases many allelopathic compounds that influence the development of neighboring flora (Anjum and Bajwa, 2008) and they affect germination of seeds (Hozayn *et al.*, 2011). Weed density is reduced ranging from 19 to 49 %, by using allopathic plants (Cheema and Khaliq, 2000). Towa and Xiangping (2014) reported that the weed density t were a lot influenced through the quantity of water under mulching, hand weeding and weedy plots.

Table 1. Weed density (m⁻²) and weed dry weight (g m⁻²) in mungbean as affected by allelopathic plants extract and other practices under different irrigation regimes

Weed control practices (WCP)	Weed density (m ⁻²)			Mean	weed dry weight (g m ⁻²)			Mean
	Irrigation regimes				Irrigation regimes			
	2	3	4		2	3	4	
WC	137	141	145	141 A	378	388	398	388 A
SE: 30 L ha ⁻¹	87	91	95	91 C	250	260	271	260 C
BE: 30 L ha ⁻¹	99	103	108	103 B	281	292	303	292 B
SE:+BE: 15 L ha ⁻¹ (each)	78	81	84	81 D	218	228	239	228 D
HE: 30 DAS	75	76	77	76 E	185	196	207	196 E
A: 0.2 L ha ⁻¹ + P: 0.312 L ha ⁻¹	68	71	74	71 F	154	164	175	164 F
SE:15 L ha ⁻¹ +A: 0.1 L ha ⁻¹ +P: 0.156 L ha ⁻¹	48	52	55	52 H	89	100	110	100 H
BE:15 L ha ⁻¹ +A: 0.1	58	61	64	61 G	121	132	143	132 G

L ha ⁻¹ +P: 0.156 L ha ⁻¹							
Means	81 C	85 B	88 A	--	210 C	220 B	231 A
Variable	S E	P-values	LSD. (5%)	S E	P-values	LSD. (5%)	
Irrigation (I)	0.7526 0	0.0030**	1.8414	0.06080	0.0000**	0.1487	
WCP	0.8267	0.0000**	1.6520	1.1666	0.0000**	2.3312	
I x WCP	1.4319	0.0000**	2.8614	2.0205	0.0000**	4.0377	

WC=Weedy check, SE=Sunflower extract, BE= Bermuda grass extract, HW=Hand weeding, A=Atlantis, P= Puma super NS= Non-significant at $P_{0.05}$; *= Significant at $P_{0.05}$; **= Significant at $P_{0.01}$.

Weed dry weight (g m⁻²)

All treatments significantly reduced weed dry weight compared with weedy check (untreated) (Table 1). The data revealed that the mixture of sunflower extract @ 15 L ha⁻¹ + herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) provided reduced (100 g m⁻²) weed dry weight followed by incorporation of bermuda grass extract @ 15 L ha⁻¹ with herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) resulting in 132 g m⁻² weed dry weight against weed dry of 388 g m⁻² recorded in weedy check (untreated). Irrigation levels also significantly affected the weed dry weight. Two irrigations (30 and 60 DAS) distinguished the minimum weed dry weight (210 g m⁻²) followed by three irrigations (220 g m⁻²) while maximum weed dry weight (231 g m⁻²) was noted in four irrigations. Substantial interactive effect of weed control practices × irrigation levels was documented for weed dry weight. Towa and Xiangping (2014) described that the weed dry weight were significantly affected by the quantity of water under all the mulching, hand weeding and weedy plots.

Seed germination (m⁻²)

Various weed control practices reflected a positive influence in seed germination of mungbean. The weed control practices showed significant ($P < 0.05$) results for seed germination (Table 2). The maximum (36.09 m⁻²) seed germination was noted under the combination of sunflower extract @ 15 L ha⁻¹ with herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) trailed by integration of bermuda grass extract @ 15 L ha⁻¹ with herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) with 35.01 m⁻² seed germination. However, minimum (26.36 m⁻²) seed germination was found under weedy check (untreated). Among irrigation frequencies, four irrigations noticed in maximum (32.40 m⁻²) seed germination as compared to three irrigations and two irrigations (32.04 and 31.68 m⁻²). Remarkable effect of interaction of weed control practices × irrigation frequencies was observed for seed germination (m⁻²). The water extracts of allelopathic crops caused substantial reduction in germination and growth of tested summer

weeds such as jungle rice (*Echinochloa colonum* L.), bermuda grass (*Cynodon dactylon* L.) and purple nutsedge (*Cyperus rotundus* L.) (Kandhro *et al.*, 2015). These results support the findings of Maharjan *et al.* (2007) who found that leaf water extracts of *Parthenium hysterophorus*

exhibited significant reduction effects on germination of seeds and seedling development, Similarly Bajwa *et al.* (2004) reported that aqueous extract from shoot of *Parthenium* reduced the germination and seedling growth.

Table 2. Seed germination (m⁻²) and leaf area index in mungbean as affected by allelopathic plants extract and other practices under different irrigation regimes

Weed control practices (WCP)	Seed germination (m ⁻²)			Mean	leaf area index			Mean
	Irrigation regimes				Irrigation regimes			
	2	3	4		2	3	4	
WC	26.00	26.36	26.73	26.36 H	3.10	3.14	3.18	3.14 H
SE: 30 L ha ⁻¹	30.33	30.69	31.05	30.69 F	3.58	3.63	3.68	3.63 F
BE: 30 L ha ⁻¹	29.25	29.61	29.97	29.61 G	3.46	3.50	3.54	3.50 G
SE:+BE: 15 L ha ⁻¹ (each)	31.41	31.77	32.13	31.77 E	3.73	3.78	3.83	3.78 E
HE: 30 DAS	32.49	32.85	33.21	32.85 D	3.88	3.93	3.98	3.93 D
A: 0.2 L ha ⁻¹ + P: 0.312 L ha ⁻¹	33.57	33.93	34.29	33.93 C	4.03	4.08	4.13	4.08 C
SE:15 L ha ⁻¹ +A: 0.1 L ha ⁻¹ +P: 0.156 L ha ⁻¹	35.73	36.10	36.46	36.09 A	4.33	4.38	4.88	4.53 A
BE:15 L ha ⁻¹ +A: 0.1 L ha ⁻¹ +P: 0.156 L ha ⁻¹	34.65	35.01	35.37	35.01 B	4.18	4.23	4.28	4.23 B
Means	31.68 C	32.04 B	32.40 A	--	3.79 C	3.83 B	3.94 A	--
Variable	S E		P-values	LSD. (5%)	S E		P-values	LSD. (5%)

Irrigation (I)	2.94604	0.0000**	0.0072	6.37403	0.0000**	0.0156
WCP	1.31103	0.0000**	1.0030	0.0365	0.0000**	0.0729
I x WCP	2.27103	0.0428*	4.53903	0.0632	0.0000**	0.1262

WC=Weedy check, SE=Sunflower extract, BE= Bermuda grass extract, HW=Hand weeding, A=Atlantis, P= Puma super NS= Non-significant at $P_{0.05}$; *= Significant at $P_{0.05}$; **= Significant at $P_{0.01}$.

Leaf area index

The data (Table 2) revealed that various weed control practices significantly improved leaf area index of mungbean in contrast to control (weedy check). The data of leaf area index was noted high (4.53) in plot under combination of sunflower extract @ 15 L ha⁻¹ with herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) followed by integration of bermuda grass extract @ 15 L ha⁻¹ with herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) (4.23) and low (3.14) was noticed in weedy check (untreated). Four irrigations produced maximum (3.94) leaf area index trailed by three irrigations with 3.83 leaf area index. Nevertheless, less (3.79) leaf area index was noticed in two irrigations. Significant interaction of weed control practices × irrigation frequencies were observed for leaf area index.

Pods plant⁻¹

The data (Table 3) regarding pods per plant showed significant effect of weed

control practices. Combination of sunflower extract @ 15 L ha⁻¹ + herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) gave significantly highest pods plant⁻¹ of 36.26 followed by integration of bermuda grass extract @ 15 L ha⁻¹ + herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) which produced (34.76) whereas lowest (23.07) pods plant⁻¹ were obtained in weedy check (untreated). It is also noticeable that irrigation levels influenced significantly on pods plant⁻¹. Four irrigations produced maximum (31.24) pods plant⁻¹ followed by three irrigations with 30.72 pods plant⁻¹. Nonetheless, least (30.25) pod plant⁻¹ were noted in two irrigations. The interaction of weed control practices × irrigation frequencies was found significant for pods plant⁻¹. Din and Parvin (2013) reported that water stress affects different growth and developmental stages of mungbean. The increase in watering application caused significant increase in the number of pods plant⁻¹ (Albinet, 2000).

Table 3. Pods plant⁻¹ and seed weight pod⁻¹ (g) in mungbean as affected by allelopathic plants extract and other practices under different irrigation regimes

Weed control practices (WCP)	Pods plant ⁻¹			Mean	seed weight pod ⁻¹ (g)			Mean
	Irrigation regimes				Irrigation regimes			
	2	3	4		2	3	4	
WC	22.53	23.01	23.67	23.07 H	0.42	0.42	0.43	0.42 H
SE: 30 L ha ⁻¹	28.41	28.89	29.37	28.89 F	0.51	0.52	0.53	0.52 F
BE: 30 L ha ⁻¹	27.03	27.45	27.93	27.47 G	0.48	0.49	0.50	0.49 G
SE:+BE: 15 L ha ⁻¹ (each)	29.86	30.35	30.84	30.35 E	0.54	0.55	0.56	0.55 E
HE: 30 DAS	31.33	31.82	32.31	31.82 D	0.57	0.58	0.59	0.58 D
A: 0.2 L ha ⁻¹ + P: 0.312 L ha ⁻¹	32.80	33.29	33.78	33.29 C	0.60	0.61	0.62	0.61 C
SE:15 L ha ⁻¹ +A: 0.1 L ha ⁻¹ +P: 0.156 L ha ⁻¹	35.74	36.23	36.82	36.26 A	0.66	0.67	0.68	0.67 A
BE:15 L ha ⁻¹ +A: 0.1 L ha ⁻¹ +P: 0.156 L ha ⁻¹	34.27	34.76	35.25	34.76 B	0.63	0.64	0.65	0.64 B
Means	30.25 C	30.72 B	31.24 A	--	0.55 C	0.56 B	0.57 A	--
Variable	S E	P-values	LSD. (5%)	S E	P-values	LSD. (5%)		
Irrigation (I)	0.01780	0.0000**	0.0436	2.891030	0.0001**	0.0070		
WCP	0.0424	0.0000**	0.0848	8.21403	0.0000**	0.0164		
I x WCP	0.0735	0.0033**	0.1468	0.0142	0.0000**	0.0284		

WC=Weedy check, SE=Sunflower extract, BE= Bermuda grass extract, HW=Hand weeding, A=Atlantis, P= Puma super NS= Non-significant at P_{0.05}; *= Significant at P_{0.05}; **= Significant at P_{0.01}.

Seed weight pod⁻¹ (g)

The combination of sunflower extract @ 15 L ha⁻¹ with herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) revealed significantly greatest seed weight pod⁻¹ of 0.67 g. The integration of bermuda grass extract @ 15 L ha⁻¹ with herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) followed and created seed weight pod⁻¹ of 0.64 g and lowest (0.42 g) seed weight pod⁻¹ was achieved in weedy check (untreated). Seed weight pod⁻¹ was significant regarding irrigation frequencies effects. Four irrigations resulted in more 0.57 g seed weight pod⁻¹ followed by three irrigations which produced seed weight of 0.56 g pod⁻¹. However, less 0.55 g seed weight pod⁻¹ was recorded in two irrigations. The interaction of weed control practices × irrigation frequencies was found substantial for seed weight pod⁻¹ (Table 3).

Biological yield (kg ha⁻¹)

The weed control practices noticed significant (P<0.05) results for crop

biological yield (Table 4) of mungbean. The more (4945 kg ha⁻¹) biological yield was found under the combination of sunflower extract @ 15 L ha⁻¹ with herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) followed by integration of bermuda grass extract @ 15 L ha⁻¹ with herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) resulting in 4815 kg ha⁻¹ and lowest (3874 kg ha⁻¹) biological yield was achieved in weedy check (untreated). Four irrigations provided highest (4564 kg ha⁻¹) biological yield as compared to three and two irrigations (4539 and 4384 kg ha⁻¹). The interactive effects of weed control practices × irrigation frequencies were found significant for biological yield (kg ha⁻¹). These findings are similar as shown by Cheema and Khaliq (2000) who exposed increased biological yield due to weed control in wheat. Similarly, Sangakara (1994) reported that the growth and yield of mungbean crop significantly improved by the availability of sufficient soil moisture.

Table 4. Biological yield (kg ha⁻¹) and seed yield (kg ha⁻¹) in mungbean as affected by allelopathic plants extract and other practices under different irrigation regimes

Weed control practices (WCP)	Biological yield (kg ha ⁻¹)			Mean	seed yield (kg ha ⁻¹)			Mean
	Irrigation regimes				Irrigation regimes			
	2	3	4		2	3	4	
WC	3764	3917	3942	3874 H	1254	1352	1383	1330 H
SE: 30 L ha ⁻¹	4236	4389	4413	4346 F	1716	1813	1844	1791 F
BE: 30 L ha ⁻¹	4119	4272	4296	4229 G	1596	1694	1725	1671 G
SE:+BE: 15 L ha ⁻¹	4354	4508	4533	4465 E	1835	1932	1963	1910 E

(each)								
HE: 30 DAS	4474	4628	4653	4585 D	1954	2052	2083	2029 D
A: 0.2 L ha ⁻¹ + P: 0.312 L ha ⁻¹	4594	4748	4763	4702 C	2074	2171	2203	2149 C
SE:15 L ha ⁻¹ +A: 0.1 L ha ⁻¹ +P: 0.156 L ha ⁻¹	4824	4988	5024	4945 A	2313	2411	2449	2391 A
BE:15 L ha ⁻¹ +A: 0.1 L ha ⁻¹ +P: 0.156 L ha ⁻¹	4704	4858	4883	4815 B	2193	2291	2322	2269 B
Means	4384 B	4539 A	4564 A	--	1867 B	1965 A	1996 A	--
Variable	S E	P-values	LSD. (5%)	S E	P-values	LSD. (5%)		
Irrigation (I)	0.76840	0.0000**	26.8802	0.09200	0.0000**	32.2252		
WCP	2.3816	0.0000**	4.7593	0.5618	0.0000**	1.1226		
I x WCP	4.1251	0.0118*	8.2434	0.9730	0.0000**	1.9444		

WC=Weedy check, SE=Sunflower extract, BE= Bermuda grass extract, HW=Hand weeding, A=Atlantis, P= Puma super NS= Non-significant at P_{0.05}; *= Significant at P_{0.05}; **= Significant at P_{0.01}.

Seed yield (kg ha⁻¹)

The data (Table 4) exposed that different weed control practices treatments significantly improved seed yield attributes of mungbean in contrast to weedy check (untreated). The combination of sunflower extract @ 15 L ha⁻¹ with herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) considerably produced more seed yield (2391 kg ha⁻¹) over integration of bermuda grass extract @ 15 L ha⁻¹ + herbicides (atlantis @ 0.1 L ha⁻¹ + puma super @ 0.156 L ha⁻¹) resulting in 2269 kg ha⁻¹. Nevertheless, lowest (1330 kg ha⁻¹) seed yield was noticed in weedy check

(untreated). Seed yield was also significantly inflated by irrigation frequencies. Four irrigations produced greater (1996 kg ha⁻¹) seed yield followed by three irrigations with 1965 kg ha⁻¹ and lesser 1867 kg ha⁻¹ seed yield was noted under two irrigations. Significant interactive effects of weed control practices × irrigation frequencies were found for seed yield (kg ha⁻¹). Combined utilization of allelopathic plants extracts is more helpful for controlling weeds as compared to alone (Cheema *et al.*, 2003). Control of weeds through allelopathic plant extract enhanced yield from 15 to 25% (Cheema *et al.*, 2013). Raza *et al.*

(2012) concluded that more seed yield of mungbean crop obtained with optimum watering.

Conclusion

The present research suggested that combination of sunflower extract with low dose of herbicide (sunflower extract: 15 L ha⁻¹ + atlantis: 0.1 L ha⁻¹ + puma super: 0.156 L ha⁻¹) reduce weeds and enhanced mungbean seed yield remarkably. Amongst irrigation frequencies, three times application of irrigation was found appropriate for controlling weeds and obtaining optimal seed yield of mungbean along with application of sunflower water extract and reduced dose of herbicides.

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Novelty Statement

The present research work investigated the allelopathic effect of sunflower and bermuda grass extract in conjunction with irrigation frequencies on weed management and yield improvement in mungbean for the first time under Tandojam conditions. This could help in weed reduction and yield enhancement in the local conditions.

Author's Contribution

M.N. Korejo planned experiment, data collection and prepared manuscript. M.N. Kandhro guided scholar as a whole from designing experiment to writing of manuscript. A.A. Soomro provided research facility and helped in manuscript write-up. N.A. Wahocho helped in research material, data analysis and interpretation of results.

Conflict of interest

There is no conflict of interest among authors.

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