Research Article

Response of Cereals Crops and Associated Weeds to Moringa Aqueous Extract Application on Their Growth Metrics

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Abstract | Allelopathy has emerged as a pragmatic approach to address multiple issues in modern agriculture. Allelochemicals released from plant residues in the rhizosphere improve nutrient acquisition through solubilization, biological nitrification, inhibition, chelation, and selective retention. These compounds promote growth at low concentrations but may suppress it at higher levels. Keeping this in view the stimulatory behavior of MLE an investigation was conducted to evaluate the allelopathic effect of a 20% (w/v) aqueous extract of *Moringa oleifera* L. leaves on the germination and growth indices of different cereal crops including wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), barley (*Hordeum vulgare* L.), sorghum (*Sorghum bicolor* L.), and millet (*Pennisetum americanum* L.) with some common weeds i.e., *Avena fatua, Echinochloa clona* L., *Cyprus rotundus, Convolvulus arvensis and Chenopodium album.* A control treatment was maintained for comparison. Data were recorded on germination and growth parameters of cereals and weeds were significant at 5% probability level. The results revealed that the aqueous extract of *M. oleifera* differentially affected all cereal crops compared to the control. Similar behavior of MLE extract was noted in weeds. Wheat exhibited a slight increase in shoot length (from 14.72 to 15.6 cm) but reduced root length (from 19.26 to 12.82 cm) and a marginal decline in fresh weight (from 4.23 to 3.20 g plant^{-1}). Maize responded positively with an increase in fresh weight from 14.77 to 16.31 g plant^{-1}, dry weight from 2.4 to 3.2 g, and leaf area from 22.33 to 25.26 cm^2 plant^{-1}, though root elongation was reduced. Barley showed an improvement in shoot length (11.34 to 13.44 cm) and leaf area (13.14 to 17.21 cm^2 plant^{-1}) but experienced a decrease in dry weight (1.2 to 0.91 g). Sorghum showed no inhibitory effect on germination (6 days in both treatments) but had higher shoot and root biomass (fresh weight: 13.68 to 15.76 g plant^{-1}; dry weight: 3.4 to 3.9 g). Millet recorded the highest improvement in leaf area (19.33 to 26.21 cm^2 plant^{-1}) and growth rate (11.2 to 15.21 g m^{-2} day^{-1}). MLE also improved the germination metrics and early growth indices of weeds. Moringa Oleifera aqueous extract has both growth-promoting and growth-inhibiting effects depending on the crop and weeds likely due to its phytohormones and allelochemicals. While beneficial for crops like wheat and barley, it may suppress others cereal upto some extent and stimulate weeds. Therefore, its use must be species-specific, concentration-controlled and further researched for safe agricultural application.

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Introduction

Cereal crops constitute the cornerstone of global agriculture and food systems, contributing more than half of the total caloric intake of the world's population (Mesías *et al*., 2024). Among them, wheat, rice, maize, barley, sorghum, and millet serve as staple foods in both developing and developed nations (Makinen *et al*., 2024). These crops not only provide essential carbohydrates, proteins, vitamins, and minerals but also form the basis of livestock feed and several industrial products. The adaptability of cereals to diverse agro-ecological zones makes them critical for sustainable crop production. Enhancing the productivity and resilience of cereal crops is, therefore, fundamental to achieving food security, especially under the pressures of population growth, climate change, and land degradation (Shi *et al*., 2021). *Moringa oleifera* L. is native to the sub-Himalayan environmental zone of the Indo-Pak region (Shahzad *et al*., 2013) and exhibits wide genetic diversity. There are at least three distinct landraces in Pakistan, including the white-seeded type from Faisalabad (MFSD), the black-seeded type from Multan (MMUL), and PKM1, a cultivated variety from India (Coppin *et al*., 2013). This diversity provides opportunities to identify the most effective bio stimulant sources from M. oleifera leaf extract.

Weeds are among the most persistent biological constraints limiting cereal productivity worldwide. They compete with crops for vital resources such as nutrients, water, light, and space, resulting in substantial yield losses. In addition to direct competition, many weed species release allelopathic compounds that inhibit seed germination and seedling growth of cereals, further reducing crop establishment and vigor. Conversely, some cereal species also exhibit allelopathic potential, releasing biochemical substances from roots or crop residues that suppress weed emergence (Hussain *et al*., 2019). Understanding these allelopathic interactions provides valuable opportunities to develop eco-friendly weed management strategies and reduce dependence on synthetic herbicides, thereby promoting sustainable cereal production and environmental health. (Mushtaq *et al*., 2024).

Bio stimulants are natural crop growth promoters that not only enhance crop yield and quality but also protect plants against various abiotic stresses such as drought, salinity, temperature extremes, and nutrient deficiencies. (European Bio stimulant Industry Council [EBIC], 2012). Among them, M. oleifera leaf aqueous extract, sorghum extract, and mulberry extract are widely used as plant growth regulators when applied as seed priming agents and/or foliar sprays. These extracts positively influence plant growth and productivity by modifying metabolic processes under both normal and stress conditions (Rady *et al*., 2013; Yasmeen *et al*., 2013b; Semida and Rady, 2014).

Moringa oleifera L. among all natural growth stimulants, has attracted significant scientific interest due to its high content of growth hormones, antioxidants, vitamins, and mineral nutrients (Shinano and Kasase, 2009; Yasmeen *et al*., 2013a; Bakhtawar *et al*., 2015). Seed priming with M. oleifera leaf extract blended with salicylic acid, hydrogen peroxide, ascorbic acid, or sorghum water extract enhances germination and seedling performance in maize (Imran *et al*., 2013). Similarly, foliar application of M. oleifera extract with benzyl amino purine and hydrogen peroxide at critical growth stages in wheat significantly improves growth, development, and yield (Yasmeen *et al*., 2013b).

Seed priming and foliar application of M. oleifera extract alone or in combination with kinetin significantly improve stand establishment, chlorophyll content, crop growth rate, photosynthetic rate, leaf area index, and yield of both normal and late-sown maize (Bakhtawar *et al.*, 2015). Exogenous application of *M. oleifera* extract via seeds or foliage promotes emergence, seedling growth, and development in several field crops under both normal and adverse conditions (Basra *et al.*, 2011). Its use as a priming agent shortens emergence time, enhances germination rate, synchronizes germination, and improves stand establishment in wheat and rice (Afzal *et al.*, 2002; Farooq *et al.*, 2008). Such improvements are attributed to enhanced physiological, biochemical, and agronomic traits such as greater leaf area, delayed senescence, increased antioxidant activity, and higher chlorophyll, ascorbic acid, and phenolic contents, which collectively improve plant resistance to stress and enhance economic returns (Yasmeen *et al.*, 2013a, 2013b). Furthermore, blending M. oleifera leaf extract with other natural promoters such as salicylic acid, hydrogen peroxide, and ascorbic acid produces synergistic effects on germination and seedling vigor (Imran *et al.*, 2013). A trial was initiated to determine the response of cereals and common weeds to MLE regarding their germination and early growth traits.

Materials and Methods

In terms of climate Dera Ismail Khan is categorized as semi-arid subtropical climate characterized by hot summers, mild winters, and low, erratic rainfall. The region experiences an average annual temperature of around 25 ± 2 °C, with mean annual precipitation of 250–300 mm and relative humidity ranging between 45–60% during the cereal crop sowing period, providing typical conditions for field experiments on cereals in this area.

Study site

A laboratory-based study was carried out at Post-graduate Agronomy Lab., Faculty of Agriculture, Gomal University, Dera Ismail Khan, KPK., Pakistan.

Experimental soil characteristics

Soil features	Unit	Value
pH	-	8.5
Sodium adsorption ratio (SAR)	-	11.6
Electrical conductivity (EC)	ds m^{-1}	1.75
Sand	%	36.40
Silt	%	24.80
Clay	%	45.8
Soil texture	-	Clay loam
Organic matter	%	0.41

Collection of cereals seed

Certified seed of cereals (wheat, barley, maize, millet and sorghum) was collected from Agricultural Research Institute, Ratta Kulachi, Dera Ismail Khan, KPK.

Collection of weed seeds

Seeds and tubers of common weeds associated with cereal crops were collected from research fields of Agricultural Research Institute, Ratta Kulachi, Dera Ismail Khan. The selected species included *Avena fatua*, *Jungli rice* (*Echinochloa colona*), *Cyperus rotundus*, *Convolvulus arvensis*, and *Chenopodium album*. The collected material was cleaned, air-dried, and stored in paper bags until use. Six seeds or propagules of each weed species were sown in 500 mL disposable glasses containing 300 g sandy loam soil, following the same experimental and application procedure used for cereals.

Collection of moringa oleifera leaves

5 Kg fresh leaves of *M. oleifera* were collected from the village Lunda Sharif, Tehsil Parova, District Dera Ismail Khan (KPK). The collected leaves were kept drying at ambient temperature for 15 days. After completely drying, the leaves were grinded with the help of electric blender and powder was made.

Preparation of moringa oleifera aqueous extract

The aqueous solution of *M. oleifera* was prepared by dissolving 25 g leaf powder of *M. oleifera*in to 1000 ml of distilled water in 1000ml volumetric flask at a ratio of 1:25 w/v. The flask was then placed at room temperature for 72 hours. The solution was then sieved through a double layer muslin cloth.

Experimental design and material used

The experimental design to carry out research was CRD with six replications. A local/check treatment was also included for the comparison of treatments mean. The crops studied including (wheat, barley, maize, millet and sorghum) and weeds (*Avena fatua, Echinochloa clona* L., *Cyprus rotundus, Convolvulus arvensis and Chenopodium album).* 172 disposable glasses of volume 500 ml were taken, and each glass was filled with 300 gram of sandy loam soil. 6 seeds of each crop at a depth of 2 cm were sown in each disposable glass. The data on different parameter were recorded at 20 days after germination.

Method of moringa oleifera leaf extract application

The first application of MLE was applied to each glass except control after sowing and the remaining at three days interval @ 150 ml to each time.

Data analysis

The collected data were analyzed using the Analysis of Variance (ANOVA) technique through the Statistical Analysis System (SAS) software at a 5% probability level. Significant differences among treatment means were separated using Fisher's Least Significant Difference (LSD) test as per the procedure described by Gomez and Gomez, (1998).

Results

Germination percentage (%)

Tables 2 and 3 indicated day to germination of serial and weeds respectively. Germination varied notably among cereal and weed species in response to moringa aqueous extract. In cereals, the extract generally enhanced germination uniformity and seedling emergence. Maize and sorghum recorded slightly delayed but more synchronized germination, increasing from 5 to

Table 1: *Physiological traits of cereals as affected by moringa aqueous leaf extract.*

Crops	Plant fresh weight plant^{-1} (g)		Plant dry weight (g)		Plant growth rate (g m^{-2} day^{-1})		Net assimilation rate (g m^{-2} day^{-1})	
	Control	extract	Control	extract	Control	extract	Control	extract
Wheat	4.23 d	3.2 d	0.45 c	0.43 b	3.21 c	3.02 c	0.32^{NS}	0.31^{NS}
Maize	14.77 a	16.31 a	2.4 ab	3.2 a	12.25 a	14.31 a	1.36	0.31
Barley	6.33 c	7.21 c	1.2 bc	0.91 b	5.36 b	6.01 b	0.42	1.52
Sorghum	13.68 a	15.76 a	3.4 a	3.9 a	10.26 ab	14.03 a	0.76	0.45
Millet	12.43 b	15.43 b	1.9 b	2.6 ab	11.2 a	15.21 a	0.91	0.97

Table 2: *Morphological traits of cereals as affected by moringa aqueous leaf extract.*

Crops	Shoot length (cm)		Root length (cm)		Leaf area plant $^{-1}$(cm^2)		Days to germination	
	Control	extract	Control	extract	Control	Extract	Control	extract
Wheat	14.72	15.6	19.26	12.82	12.75 c	8.23 c	7	8
Maize	14.98	10.4	13.6	8.48	22.33 a	25.26 a	5	6
Barley	11.34	13.44	13.08	12.56	13.14 c	17.21 b	7	8
Sorghum	10.5	8.64	13.18	6.38	23.22 a	24.23 a	6	6
Millet	5.4	3.92	11.28	5.32	19.33 b	26.21 a	7	6

Table 3: *Physiological traits of weeds as affected by moringa aqueous leaf extract*

Category	Weeds	Shoot length (cm)		Root length (cm)		Leaf area plant^{-1}(cm^2)		Days to germination	
		Control	extract	Control	extract	Control	extract	Control	extract
Narrow leaf weeds	Avena fatua	12.2 a	15.3 a	11.23 a	17.03 a	2.22 c	2.87 c	6 b	4 b
	Jungli rice	10.3 b	13.4 b	9.34 b	16.31 a	1.33 c	1.77 c	4 b	4 b
	Cyprus rotundus	11.15 b	16.7 a	9.26 b	9.41 b	1.02 c	1.12 c	8 a	5 a
Broad leaf weeds	Convolvulus arvensis	12.3 a	19.5 c	9.29 b	7.31 c	3 b	4.2 a	5 b	4 b
	Chenopodium album	8.7 c	6.5 d	12.22 a	10.39 b	4.23 a	4.99 c	4 b	4 b

Table 4: *Morphological traits of weeds as affected by moringa aqueous leaf extract*

Category	Weeds	Fresh weight (g)		Plant dry weight (g)		Plant growth rate (g m^{-2} day^{-1})		Net assimilation rate (g m^{-2} day^{-1})	
		Control	extract	Control	extract	Control	extract	Control	extract
Narrow leaf weeds	Avena fatua	4 a	6.23 a	1.23 a	1.77 a	3.19 a	4.33 ab	0.42^{NS}	0.63^{NS}
	Jungli rice	3.29 b	4.56 b	0.97 ab	1.31 ab	2.3 b	2.45 bc	0.32	0.37
	Cyprus rotundus	3.31 b	5.26 ab	1.03 a	1.34 ab	4.43 a	6.21 a	0.56	0.61
Broad leaf weeds	Convolvulus arvensis	2.21 c	2.05 c	0.75 b	0.55 b	1.21 b	1.79 c	0.23	0.47
	Chenopodium album	4.5 a	3.75 bc	1.25 a	0.92 b	1.45 b	2.21 c	0.37	0.56

6 days and 6 to 6 days, respectively. Barley showed a minor delay from 7 to 8 days, while wheat and millet exhibited slight variation (7 to 8 and 7 to 6 days, respectively), indicating crop-specific responses to moringa-induced biochemical stimulation.

Among weeds, a reduction in germination days was more evident. *Avena fatua* germination accelerated from 6 to 4 days, *Cyperus rotundus* from 8 to 5 days, and *Convolvulus arvensis* from 5 to 4 days, reflecting the stimulatory influence of moringa bioactive compounds on metabolic activation and enzyme activity during early seedling growth. This suggests that moringa extract, while beneficial to cereals, may also enhance germination of associated weed flora due to similar physiological mechanisms affecting seed metabolism.

Days to germination

Germination timing in cereals showed slight variation. Wheat and barley germinated in 8 days compared to 7 days in control. Maize showed a delay from 5 to 6 days. Sorghum remained unchanged at 6 days. Millet germination accelerated from 7 days to 6 days. Data about days to germination in cereal is not significant (Table 2) and weeds (Table 3) showed significant variation.

Among weeds, Cyperus rotundus showed a reduction in germination time from 8 days to 5 days. Avena fatua and Convolvulus arvensis germinated earlier (from 6 to 4 days and 5 to 4 days respectively). Jungli rice and Chenopodium album-maintained germination time at 4 days.

Leaf area per plant

Leaf area responded variably among species (Table 2). In cereals, millet showed the largest increase from 19.33 cm^2 to 26.21 cm^2. Maize increased from 22.33 cm^2 to 25.26 cm^2, sorghum from 23.22 cm^2 to 24.23 cm^2, and barley from 13.14 cm^2 to 17.21 cm^2. Wheat showed a decline from 12.75 cm^2 to 8.23 cm^2. Weeds mostly showed increased leaf area. *Chenopodium album* rose from 4.23 cm^2 to 4.99 cm^2, *Convolvulus arvensis* from 3.0 cm^2 to 4.2 cm^2, *Avena fatua* from 2.22 cm^2 to 2.87 cm^2, *Jungli rice* from 1.33 cm^2 to 1.77 cm^2, and *Cyperus rotundus* from 1.02 cm^2 to 1.12 cm^2 (Tables 3).

Leaf area plays a pivotal role in photosynthetic performance, as it determines the light interception capacity and contributes directly to the Net Assimilation Rate (NAR) and overall Plant Growth Rate (PGR). A larger leaf area enhances carbon assimilation and biomass accumulation, thereby improving crop vigor and productivity (Nowak *et al*., 2024).

Shoot length

Application of Moringa oleifera aqueous leaves extract induced notable changes in shoot length among cereals and weeds (Tables 2 and 3). In cereals, wheat shoot length increased from 14.72 cm (control) to 15.6 cm (treated). Barley showed an increase from 11.34 cm to 13.44 cm. In contrast, maize shoot length reduced from 14.98 cm to 10.4 cm, sorghum from 10.5 cm to 8.64 cm, and millet from 5.4 cm to 3.92 cm.

Among weeds, Convolvulus arvensis exhibited a significant increase in shoot length from 12.3 cm to 19.5 cm. *Cyperus rotundus* showed an increase from 11.15 cm to 16.7 cm, Avena fatua from 12.2 cm to 15.3 cm, and Jungli rice (*Echinochloa colona* L.) from 10.3 cm to 13.4 cm. However, Chenopodium album L. showed a reduction from 8.7 cm to 6.5 cm.

Root length

The extract mostly suppressed root growth in cereals. Wheat root length decreased from 19.26 cm to 12.82 cm. Maize declined from 13.6 cm to 8.48 cm, sorghum from 13.18 cm to 6.38 cm, and millet from 11.28 cm to 5.32 cm. Barley showed a minor reduction from 13.08 cm to 12.56 cm (Table 2).

Conversely, several weed species showed improvement in root lengths (Table 3). Avena fatua increased from 11.23 cm to 17.03 cm, and Jungli rice from 9.34 cm to 16.31 cm. Cyperus rotundus showed a slight increase from 9.26 cm to 9.41 cm. On the other hand, Convolvulus arvensis declined from 9.29 cm to 7.31 cm, and Chenopodium album from 12.22 cm to 10.39 cm.

Plant fresh and dry weight

Table 1 showed significant variation in different species of cereal. Among cereals, maize increased in fresh weight from 14.77 g to 16.31 g and in dry weight from 2.4 g to 3.2 g. Sorghum increased from 13.68 g to 15.76 g (fresh) and 3.4 g to 3.9 g (dry). Millet showed growth from 12.43 g to 15.43 g (fresh) and 1.9 g to 2.6 g (dry). Barley increased from 6.33 g to 7.21 g (fresh) while dry weight decreased slightly from 1.2 g to 0.91 g. Wheat declined in both fresh weight (from 4.23 g to 3.2 g) and dry weight (from 0.45 g to 0.43 g).

In weeds, Avena fatua showed the highest values, increasing from 4 g to 6.23 g (fresh) and 1.23 g to 1.77 g (dry). Jungli rice increased from 3.29 g to 4.56 g (fresh) and 0.97 g to 1.31 g (dry). Cyperus rotundus also increased from 3.31 g to 5.26 g (fresh) and 1.03 g to 1.34 g (dry). Convolvulus arvensis decreased from 2.21 g to 2.05 g (fresh) and 0.75 g to 0.55 g (dry). Chenopodium album dropped from 4.5 g to 3.75 g (fresh) and from 1.25 g to 0.92 g (dry) (Table 4).

Plant growth rate

Data about plant growth rate are elaborated in Table 1 about cereal. Millet among cereals had the highest growth rate increase from 11.2 to 15.21 g m^{-2} day^{-1}. Maize increased from 12.25 to 14.31 g m^{-2} day^{-1}, sorghum from 10.26 to 14.03 g m^{-2} day^{-1}, and barley from 5.36 to 6.01 g m^{-2} day^{-1}. Wheat showed a slight reduction from 3.21 to 3.02 g m^{-2} day^{-1}.

Means variation found in weeds are recorded in Table 4 Among weeds, Cyperus rotundus increased from 4.43 to 6.21 g m^{-2} day^{-1}, *Avena fatua* from 3.19 to 4.33 g m^{-2} day^{-1}, *Echinochloa colona* from 2.3 to 2.45 g m^{-2} day^{-1}, *Convolvulus* arvensis from 1.21 to 1.79 g m^{-2} day^{-1}, and Chenopodium album from 1.45 to 2.21 g m^{-2} day^{-1}.

Plant Growth Rate represents the rate at which a plant accumulates dry matter over time and serves as a reliable indicator of overall plant vigor and productivity. It reflects the combined influence of photosynthetic efficiency, nutrient assimilation, and environmental conditions on biomass accumulation. A higher PGR indicates greater efficiency in converting absorbed resources into structural and metabolic biomass, contributing to better growth performance (Westermann *et al*., 2024).

Net assimilation rate

NAR represents the rate of dry matter accumulation per unit leaf area and time. Barley showed a significant increase in NAR among cereals, rising from 0.42 to 1.52 g m^{-2} day^{-1} (Table 1). Millet increased from 0.91 to 0.97 g m^{-2} day^{-1}. Maize decreased from 1.36 to 0.31 g m^{-2} day^{-1}, while wheat and sorghum showed negligible or nonsignificant changes (wheat: 0.32 to 0.31 g m^{-2} day^{-1}; sorghum: 0.76 to 0.45 g m^{-2} day^{-1}).

Among weeds, NAR calculated showed specific variation (Table 4), *Avena fatua* increased from 0.42 to 0.63 g m^{-2} day^{-1}, *Cyperus rotundus* from 0.56 to 0.61 g m^{-2} day^{-1}, Jungli rice from 0.32 to 0.37 g m^{-2} day^{-1}, *Convolvulus arvensis* from 0.23 to 0.47 g m^{-2} day^{-1}, and *Chenopodium album* from 0.37 to 0.56 g m^{-2} day^{-1}.

Discussion

Germination behavior reflected species-specific allelopathic responses. The slight delays observed in wheat and barley germination (from 7 to 8 days), Table 2 suggest mild inhibitory effects of MLE at the applied concentration, whereas the acceleration in millet (7 to 6 days) indicates hormetic stimulation of enzymatic activity and hormonal regulation during seed metabolism (Yasmeen *et al*., 2012). Early germination in *Cyperus rotundus* and *Avena fatua* confirms the potential stimulatory action of MLE on certain weed species, a possible agronomic concern. Shoot and root length data (Tables 2 and 3) emphasize differential sensitivity among species. The enhanced shoot elongation in wheat and barley is consistent with the presence of cytokinins (particularly zeatin) and auxins in *M. oleifera* leaves, promoting cell division and elongation (Fahey, 2005; Basra *et al*., 2011). Conversely, the pronounced suppression of root length in maize, sorghum, and mill*et al*igns with known inhibitory effects of allelochemicals such as phenolic acids and flavonoids, which can disrupt root cell differentiation and nutrient uptake (Khanh *et al*., 2007; Shah *et al*., 2016). Biomass parameters revealed both promotive and inhibitory effects. The significant increases in maize and sorghum biomass and growth rate (e.g., maize from 14.77 to 16.31 g fresh weight) reflect improved photosynthetic efficiency and nutrient assimilation under MLE treatment (Iqbal *et al*., 2020; Rady *et al*., 2015). Conversely, reduced biomass and growth rate in wheat indicate phytotoxic sensitivity at the tested concentration (Qayyum *et al*., 2010). Weed responses were predominantly stimulatory. Species such as *Avena fatua* and *Convolvulus arvensis* exhibited increased shoot and root lengths, possibly due to hormesis—low-dose stimulation by compounds that are inhibitory at higher levels (Duke *et al*., 2015). This observation underlines a potential drawback of MLE use, as it may inadvertently enhance weed competitiveness if not applied selectively (Javaid *et al*., 2017). The substantial increase in NAR for barley (0.42 to 1.52 g m^{-2} day^{-1}) indicates elevated photosynthetic capacity and efficient carbon assimilation, corroborating previous reports of MLE's positive influence on chlorophyll content and CO_2 fixation (Yasmeen *et al*., 2012; Rady *et al*., 2015). However, maize exhibited a notable NAR decline (1.36 to 0.31 g m^{-2} day^{-1}), confirming species-specific inhibition at higher MLE concentrations (Jeber *et al*., 2014).

Conclusions and Recommendations

This study comprehensively demonstrates that *Moringa oleifera* aqueous extract exerts a highly complex and varied influence on plant growth and physiology. While it shows promise as a biostimulant for certain cereals like wheat and barley, likely due to its phytohormone content, its effects on other cereals (maize, sorghum, millet) can be inhibitory, potentially due to allelochemicals. Furthermore, the promotion of growth in several weed species necessitates careful consideration for its practical application. These findings collectively advocate for a precise, species-specific, and concentration-dependent approach to using *Moringa* extract in agricultural practices. Further research is crucial to identify optimal application rates for target crops and to fully characterize the specific compounds responsible for both the stimulatory and inhibitory effects, thereby maximizing beneficial outcomes while mitigating unintended ecological consequences.

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Novelty Statement

Moringa is a multi-purpose miracle tree. Their aqueous extracts have many secondary metabolites which have stimulatory or inhibitory actions on different plant species. Application of moringa aqueous extract on cereals and on its associated weeds is a new work for plant's scientists for their keen interest and also for farmers in sustainable green agriculture production.

Author's Contribution

Iqtidar Hussain and Mohammad Safdar Baloch: Technical help and overall management of the manuscript.
Muhammad Ammar: Principal investigator who conducted the study.
Rashid Abbas: Data analysis
Syeda Asma Batool: Proofreading
Saleem Nawaz Malik, Rashid Khan, Bismillah Khan, Syed Shahzeb Hassan and Muhammad Ismail Malik: Data collection
Muhammad Nouman Malik: Data collection and manuscript writing.

Generative AI or AI assisted technology statement
No Generative AI or AI assisted technology was used while writing manuscript or for analyzing result.

Conflict of interest
The authors have no conflict of interest.

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