



## Research Article

# Effect of Moringa Leaf Extract and its Solution Application Forms on Growth and Yield of Okra

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**Abstract** | An experiment “Effect of Moringa leaf extract and its solution application forms on growth and yield of okra” was carried out at Agriculture Research Institute North Mingora, Khyber Pakhtunkhwa, Pakistan in the year 2019. Current study was consisted of two factors and was carried out in Randomized Complete Block Design (RCBD) with three replications. Factor ‘A’ was solution application forms i.e. fresh Moringa leaf extract solution and dry Moringa leaf powder solution, while Factor B was Moringa leaf extract levels (0, 2, 4, 6, and 8%). Different forms of Moringa leaf extract solution and levels positively affected growth and yield of okra. The maximum plant height (226.1cm), flowers plant<sup>-1</sup> (34.5), number of fruit pickings (28.3), pod length (9.5 cm), pod diameter (14.6 mm), individual pod weight (11.3 g), pods plant<sup>-1</sup> (34.5), yield ha<sup>-1</sup> (14.6 tons) were noted with dry Moringa powder extract solution. Among different levels of Moringa leaf extract solution, the maximum flowers plant<sup>-1</sup> (36.3), pods plant<sup>-1</sup> (36.3), pod length (11.0 cm), pod diameter (15.8 mm), individual pod weight (12.0 g) and yield ha<sup>-1</sup> (16.4 tons) were recorded with 6% of Moringa leaf extract solution, while increased plant height (242.0 cm), number of pods pickings (29.8), and days to first pod picking (50.0) were recorded with 8% of Moringa leaf extract solution. It is recommended that dry Moringa leaf powder solution at 6% may be used to improve the growth and yield of okra crop under Swat climate.

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## Introduction

Okra belong to Genus *Abelmoschus*, Specie *esculentus* and family Malvaceae. It is locally

known as Bhindi. Among different vegetables okra is one of the oldest vegetable that is grown around the globe. Okra originated in the hotter regions of Africa and is still grown in Mediterranean basin. At present,

okra is cultivated in the areas having tropical and sub-tropical climates (Baloch, 1994).

Okra plant is herbaceous in nature which is annual and have dicot seeds. Okra grows to a height of 3-7 feet. Okra have bisexual flowers which are radially symmetrical. Okra flower is yellow in colour having five petals. The basal part of the petal is purple in colour. Fruit colour of okra varies from pale green to purple (Yamaguchi, 1983).

Okra is grown as a summer crop and is a good source of valuable compounds like, iodine, minerals, vitamins and proteins. Its immature pod are used as a vegetable while roasted seed are used as alternative for making coffee. The powder seeds are also used in making soups. Stem of the Okra is utilized in paper preparation (Hussein, 2015). Okra is used as plasma replacement or blood volume expander (Adetuyi *et al.*, 2008; Kumar *et al.*, 2010). It contains iodine and hence used as a remedy for goiter control. It is also used as remedy for numerous diseases like diabetes ulcer and chronic dysentery genito-urinary disorders (Alao *et al.*, 2011).

In Pakistan, Okra was cultivated on about 15668 hectares with 0.121 million tonnes production. Khyber Pakhtunkhwa produced about 0.017 million tons on 2183 hectares while Balochistan produced 0.014 million tons on 2392 hectares (MNFSR, 2017-2018).

In Khyber Pakhtunkhwa, the recommended months for Okra seed sowing is March-May. Okra seeds are normally sown 2-3 cm deep on ridges. The distance of 50-75 cm are kept between the ridges, while 20-30 cm are kept between plant-plant. One hectare area requires about 18-20 kg seeds. In Malakand Division, the Okra cultivation is limited, because of increase in population, construction on agricultural lands, land fragmentations, soil erosion and families structure (Khan *et al.*, 2000).

Moringa (*Moringa oleifera*) is one of the beneficial medicinal trees of Moringaceae family which is grown wildy in the tropical parts of countries like, Philippine, India, Pakistan, Hawaii and Africa (Foidle *et al.*, 2001; Shahzad *et al.*, 2013). Moringa leaves extract contains plant growth hormones (Zeatin), vitamins E, proteins, phenolic compounds, Ascorbates, amino acids and few minerals and is known for its plant

promoting affect (Rady *et al.*, 2015).

*Moringa oleifera* has various agricultural uses. Leaf extracts of Moringa has been used for the growth promotion of different crops like tomato, maize, wheat etc. Moringa leaf extract is also used for disease management and is easily available and are environment friendly. Moringa extracts has also antimicrobial properties and is very useful against disease causing pathogens such as soil borne pathogens (Ali *et al.*, 2004). Along with significant improvement in disease management it also increased yield by 20-30 %.

Many researchers has reported that Moringa leaf extracts significantly improved germination of seeds and growth and yield of different crops. It promotes growth, water balance, cell membrane stability, increase antioxidant contents in plants and hence improve crop production (Yasmeen *et al.*, 2012, 2013a). As it is cleared that Moringa leaf extract has the ability to improve both the vegetative and reproductive growth of different crops. Hence, the current study was designed to study the effect of Moringa leaf extract and its solution application forms on growth and yield of okra.

## Materials and Methods

An experiment entitled effect of Moringa leaf extract and its solution application forms on growth and yield of okra was carried out at Agriculture Research Institute, North Mingora Swat, Khyber Pakhtunkhwa Pakistan in April, 2019.

### Preparation of the field

The field was thoroughly prepared by tillage and levelled by harrow before sowing the seeds. During the experiment, the recommended levels of N P K fertilizers (25-25-25 kg ha<sup>-1</sup>) were applied at the time of field preparation. Nitrogen was given half at field preparation time and its half dose was given after first pod picking. Other important cultural practices like watering, weed removal and hoeing were managed on proper time.

### Soil analysis

Soil analysis was done in soil laboratory of ARI Mingora Swat where the soil was silt loam with pH 6.2 while CaCO<sub>3</sub> was <1% and organic matter was 1.23%.

### *Moringa leaves extraction and application*

For fresh method healthy Moringa leaves were collected from the tree and were washed. The leaves were grinded well in blinder for 15 minutes and then it was dissolved in distilled water. For example for 2%, 2 gram of fresh leaves were taken which was then blended and was dissolved in 100 ml of water after separation of pure extract with the help of muslin cloth. Similarly for dry method two gram of fresh leaves were taken which was then dried in oven and was powdered and then it was dissolved in 100 ml of water. Control treatments were treated with distilled water. After extract preparation, application of extract was done once as a foliar application after 30 days of sowing.

### *Experimental design*

Randomized Complete Block Design (RCBD) was used as an experimental design having two factors with three replications. Factor 'A' was solution application forms and Factor 'B' was different Moringa leaf extract levels. The sum of all experimental area was  $15\text{m} \times 7.5\text{m} = 112.5 \text{ m}^2$  while the plot area was  $2.5\text{m} \times 1.5\text{m} = 3.75 \text{ m}^2$ . Two ridges were used in each treatment, in which 30 cm distance were kept between plant to plant while a space of 75 cm were maintained between ridges.

### *Factor A: Solution application forms*

F<sub>1</sub> = Fresh Moringa leaves extract solution

F<sub>2</sub> = Dry Moringa leaves powder solution

### *Factor B: Moringa leaf extract levels (%)*

L<sub>1</sub> = 0

L<sub>2</sub> = 2

L<sub>3</sub> = 4

L<sub>4</sub> = 6

L<sub>5</sub> = 8

### *Parameters*

**Plant height (cm):** Measuring tape was used for measurement of plant height. Plants were measured from ground surface to the top of the plant and then their mean values were calculated.

**Branches plant<sup>-1</sup>:** Branches were counted in selected plants at the time of harvesting of every treatment and finally their average values were obtained.

**Flowers plant<sup>-1</sup>:** Flowers in the selected plants were counted at the time of bud opening in each treatment

and their mean values were computed.

**No. of pods pickings:** Each harvesting were considered as a single picking which were counted in every treatment.

**Days to 1<sup>st</sup> pod picking (days):** Days were counted in selected plants from time of sowing to first picking in each treatment and then their means were worked out.

**Pod length (cm):** Measuring tape was used for measuring pod length in every treatment and finally mean values were obtained.

**Pod diameter (mm):** Vernier calliper (digital) was used for the measurement of pod diameter in every treatment and then their means were calculated.

**Individual pod weight (g):** Electronic scale (SF-400) was used for individual pod weight in every treatment and finally their means were calculated.

**Pods plant<sup>-1</sup>:** Pods per plant were calculated by counting pods in randomly selected plants in each treatment and finally their average values were obtained.

**Yield ha<sup>-1</sup>(tons):** Yield ha<sup>-1</sup> was determined with the following formula.

$$\text{Yield ha}^{-1} (\text{tons}) = \frac{\text{Yield Plot}^{-1} (\text{kg}) \times 10000\text{m}^2}{\text{Plot area (m}^2) \times 1000}$$

### *Statistical analysis*

Analysis was done with the help of statistic software Statistix 8.1. All data were tested by the analysis of variance (ANOVA) and mean of the treatments were analysed and compared with the help of Least Significant Differences test at 1% and 5% level of significance according to (Steel and Torrie, 1980).

## **Results and Discussion**

### *Plant height (cm)*

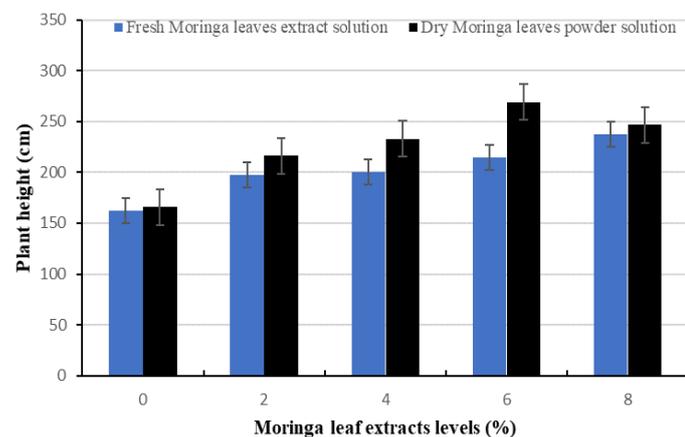
Plant height was positively improved by Moringa leaf extract levels, solution application forms and interaction (Table 1). Plants with more height (226.1 cm) were obtained with dry Moringa leaves powder solution, while lowest plant height (202.5 cm) was recorded with fresh Moringa leaves extract solution.

**Table 1:** Plant height (cm), branches plant<sup>-1</sup>, days to 1<sup>st</sup> flowering, flowers plant<sup>-1</sup>, number of pods pickings, days to 1<sup>st</sup> pod picking.

Moringa leaf extract %	Plant height (cm)	Branches plant <sup>-1</sup>	Flowers plant <sup>-1</sup>	Number of pods pickings	Days to 1 <sup>st</sup> pod picking
Control	164.0 D	1.9 c	31.7 e	24.2 C	54.3 A
2	206.8 C	2.1 b	33.0 d	26.3 B	52.5 AB
4	216.8 B	2.4 a	34.2 c	26.7 B	51.7 BC
6	241.9 A	2.4 a	36.3 a	29.0 A	51.2 BC
8	242.0 A	2.3 ab	35.3 b	29.8 A	50.0 C
LSD (0.05) for Moringa leaf extract %	4.261	0.237	0.956	1.932	2.190
<b>Solution application forms</b>					
Fresh leaves extract	2.02.5 B	2.1 b	33.7 b	26.1 B	52.1
Dry leaves extract	226.1 A	2.3 a	34.5 a	28.3 A	51.8
LSD (0.05) for SAF	2.695	0.150	0.605	1.222	NS
MLE% × SAF	***	NS	NS	NS	NS

Means values in the table having capital letters shows significance at 0.01 probability, while small letters shows significance at 0.05, respectively. \*\*\* = significant while NS means non-significant. SAF: Solution application forms, MLE: Moringa leaf extract.

Among the different Moringa leaf extract levels, plants with maximum (242cm) height was recorded with the application of 8% Moringa leaf extract (MLE) solution followed by 6% with 241.9 cm plant height, while control treatment produced plants with less (164.0 cm) height. In case of interaction, plants with maximum height (269.1 cm) were recorded with 6% solution of dry Moringa leaves powder, while plants with minimum height (162.3 cm) were recorded in untreated plot (Figure 1).



**Figure 1:** Influence of Moringa leaf extracts levels and its solution applications forms on plant height (cm).

Fresh sample shows freshness up to 3 hours after that it become weak as compared with dried sample (Sulaiman *et al.*, 2011). Also, the dried leaf extract is more concentrated than fresh leaf extract because fresh leaf extract has high moisture content (Ayodelea *et al.*, 2015), hence more concentrated extracts provide more nutrients and produce best

results. Moringa leaves contain lots of essential micro and macro-elements and sufficient amount of Gibberellic acid, IAA, and Cytokinin that specifically helps in improving vegetative growth (Yasmeen *et al.*, 2013; Rehman *et al.*, 2017). Plant height was significantly increased by 4% leaf extract of Moringa applied on pepper plants as stated by (Hala *et al.*, 2017). Tallest plants were noticed with leaf extract of Moringa in tomato crop (Culver *et al.*, 2012). Similar statements has been published by (Bashir *et al.*, 2014; Oluwagbenga and Odeghe, 2015; Muhammed *et al.*, 2013; Abdelnaser *et al.*, 2017; Rehman *et al.*, 2017) in tomato, bell pepper, onion, snap bean and wheat crop.

#### Branches plant<sup>-1</sup>

Branches per plant were positively influenced by different solution application forms and MLE levels while no affect was found in case of interaction (Table 1). Plants with increased number of branches plant<sup>-1</sup> (2.3) were recorded with dry Moringa leaves powder solution, whereas least branches plant<sup>-1</sup> (2.1) were recorded with fresh Moringa leaves extract solution. Regarding to various levels of Moringa leaf extract (MLE) solution, more (2.4) branches plant<sup>-1</sup> were noted with 4% and 6% of Moringa leaf extract (MLE) solution, while least (1.9) branches plant<sup>-1</sup> were noted in plots where no solution was sprayed.

Dry extract solution produced better results than fresh extract solution because fresh solution might be deteriorated before application. Dry leaf extract has high antioxidant compounds (Vaidya *et al.*,

2014) which provides better protection and the plant remains healthy. [Rady et al. \(2013\)](#) stated that extracts of Moringa leaves contains plant growth hormones (Zeatin), vitamin E, proteins, Ascorbates, phenols, essential amino acids and contain few mineral elements, hence it is considered as a growth stimulator for plants. These different compounds plays critical role in the physiology of plants. Increase in branches with MLE solution is because of presence of Cytokinin which promote shoots in plants. [Kanchani et al. \(2019\)](#) also noted that branches plant<sup>-1</sup> were enhanced in Okra crop by foliar application of MLE at one week interval at the rate of 10%.

#### *Flowers plant<sup>-1</sup>*

There was a significant effect of all the treatments on flowers per plant except interaction ([Table 1](#)). The increased flowers plant<sup>-1</sup> (34.5) were recorded with dry Moringa leaves powder solution, while minimum flowers plant<sup>-1</sup> (33.7) were noted with fresh Moringa leaves extract solution. Regarding various levels MLE solution, maximum flowers plant<sup>-1</sup> (36.3) were noted with 6% MLE solution which was followed by 8% with 35.3 flowers per plant while minimum (31.7) flowers plant<sup>-1</sup> were noted in plots where no solution was sprayed.

Moringa dry leaf powder and fresh extract both can be used for plant studies but mostly researchers used dry Moringa leaves powder instead of fresh Moringa leaves extract ([Azwanida, 2015](#)). In the current study dry Moringa leaves powder solution application resulted in more branches per plant which in turn produced more flowers. Moringa extract is applied as a plant growth promoter due to the sufficient amount of GA<sub>3</sub>, IAA, Cytokinin, micro and macro-elements ([Yasmeen et al., 2013](#)). [Abdelnaser et al. \(2017\)](#) stated that MLE positively increased number flowers plant<sup>-1</sup> in Snap bean crop. Similarly, [Yasmeen et al. \(2014\)](#) stated that 1:30 extract of Moringa leaves increased no. of flowers plant<sup>-1</sup> of tomato crop.

#### *Number of pods picking*

Number of pickings was significantly increased by different solution application forms and concentrations of Moringa leaf extract (MLE) solution, whereas interaction had no effect ([Table 1](#)). The highest no. of pickings (28.3) were recorded with dry Moringa leaves powder solution, while minimum number of pickings (26.1) were recorded with fresh Moringa leaves extract solution. In different levels of MLE

solution mean table indicates that maximum No. of pickings (29.8) were recorded on 8% MLE solution which was statistically similar with 6%, while least (24.2) no. of pickings were noted in control treatment.

Dry leaves extract provide more nutrients and phytochemicals to the plant and hence plant produce best result with its application. Similar report is published by [Ayodelea et al. \(2015\)](#) who stated that dry leaves has more phytochemical and antioxidant compounds than fresh leaf extracts. Cytokinin is a plant growth regulator which is found in Moringa leaves, helps in increasing the rate of mitosis, cell enlargement, translocate photosynthate from source to sink, and it also helps in induction of flowers ([Siddhuraju and Becker, 2003](#)), that might be the reason that with Moringa leaf extract maximum pickings were obtained. Use of Moringa leaf extract (MLE) on okra increased No. of pods up to 70% as compared with control as reported by ([Ozobia, 2014](#)). [Mishra \(2012\)](#) stated that No. of pickings and pods plant<sup>-1</sup> in pea crop was increased by spraying of Moringa leaf extract (MLE) due to the existence of Zeatin and Kinetin.

#### *Days to 1<sup>st</sup> pod picking*

Analysis of data revealed that days to first pod picking was significantly ( $p \leq 0.01$ ) influenced by various levels of MLE solution, while solution application forms and interaction were non-significant ([Table 1](#)). More days to 1<sup>st</sup> pod picking (54.3 days) were noted in control, followed by 2% Moringa leaf extract (MLE) solution (52.5 days), whereas minimum days to 1<sup>st</sup> pod picking (50.0 days) were recorded in 8% leaf extract of Moringa.

Different levels of MLE solution positively reduced days to 1<sup>st</sup> pod picking. The difference was just two days in comparison to control but it has great importance because those commodities which come early to the market fetch high price. The benefits will be just for two days but still farmers will earn enough income. Moringa leaf is a rich source of GA<sub>3</sub>, IAA, Cytokinin, micro and macro-elements which promotes plant productivity ([Yasmeen et al., 2013a](#)). Earliness of picking with Moringa leaf extract was noted because minimum days to flowering were also noted with Moringa leaf extract (MLE). Early fruit formation and total fruit yield was significantly enhanced by Moringa leaf extract (MLE) foliar application on pepper plant as stated by ([Hala et al.,](#)

2017). Rahman *et al.* (2017) revealed that extracts obtained from Moringa leaves helps in earliness in the phenological stages of wheat crop.

*Pod length (cm)*

Pod length was significantly influenced by all treatments except interaction which was non-significant (Table 2). The highest pod length (9.5cm) was recorded with dry Moringa leaves powder solution, while lowest pod length (9.1cm) was noted with fresh Moringa leaves extract solution. Regarding concentrations of MLE increased pod length (11.0 cm) was noted with the 6% solution of MLE, followed by 8% with 10.4cm pod length, while lowest (7.6 cm) pod length was recorded in control.

Dry Moringa leaves can be used instead of fresh leaves for extract preparation (Azwanida, 2015). Dry leaves extract is better than fresh leaf because dry leaf extract is much concentrated due to less moisture content as compare to fresh leaves extract (Ayodelea *et al.*, 2015) and provide more nutrients per gram and hence produce better result than fresh leaf extract. Pod length is increased with the spraying of Moringa leaf extract (MLE) because it contain different hormones (Zeatin and GA<sub>3</sub>) which perform vital role in cell division and elongation and so pod length. According to Hala *et al.* (2017) extracts of Moringa leaf on pepper plant considerably increased fruit length as compared to untreated plants.

*Pod diameter (mm)*

Pod diameter was significantly increased by all treatments except interaction (Table 2). The maximum pod diameter (14.6 mm) was recorded with dry Moringa leaves powder solution, while minimum pod diameter (14.0 mm) was noted with fresh Moringa leaves extract solution. In case of Moringa leaf extract solution concentrations, 6% extract of Moringa leaves resulted in pods with increased diameter (15.8 mm) which was statistically similar with 8% (15.4mm) and 4% (15.1 mm), while minimum (11.7 mm) pod diameter was recorded in control treatment.

Dry extract solution produced better results than fresh extract solution because fresh solution might be deteriorated before application. According to Rady *et al.* (2015) extracts of Moringa leaves positively increased pod diameter because of presence of Cytokinin which promote shoots in plants, hence with maximum number of shoots photosynthesis activity get improved which results in maximum fruit volume, fruit mass and pod diameter. Hala *et al.* (2017) revealed that fruit diameter and total yield was significantly affected by Moringa leaf extract spraying on pepper plant as compared with untreated plants.

*Individual pod weight (g)*

Significant ( $p \leq 0.05$ ) response was noted on individual pod weight with the influence of different solution application forms and levels of Moringa leaf extract (MLE) solution, while non-significant response was noted in case of interaction (Table 2).

**Table 2:** Pod length (cm), pod diameter (cm), individual pod weight (g), yield plot<sup>-1</sup> (kg) and yield ha<sup>-1</sup> (tons).

Moringa leaf extract %	Pod length (cm)	Pod diameter (cm)	Individual pod weight (g)	Pods per plant	Yield ha <sup>-1</sup> (tons)
Control	7.6 e	11.7 C	9.6 D	31.7 E	11.3 D
2	8.2 d	13.4 B	10.4 C	33.0 D	12.8 C
4	9.2 c	15.1 A	11.2 B	34.2 C	14.3 B
6	11.0 a	15.8 A	12.0 A	36.3 A	16.4 A
8	10.4 b	15.4 A	11.6 AB	35.3 B	15.4 AB
LSD (0.05) for Moringa leaf extract %	0.492	0.858	0.503	0.956	1.147
<b>Solution application forms</b>					
Fresh leaves extract	9.1 B	14.0 b	10.7 b	33.7 b	13.5 b
Dry leaves extract	9.5 A	14.6 a	11.3 a	34.5 a	14.6 a
LSD (0.05) for SAF	0.311	0.542	0.503	0.605	0.725
MLE% × SAF	NS	NS	NS	NS	NS

Means values in the table having capital letters shows significance at 0.01 probability, while small letters shows significance at 0.05 respectively. NS: Non-significant; SAF: Solution application forms; MLE: Moring leaf extract.

The highest individual pod weight (11.3g) was noted with dry Moringa leaves powder solution, while minimum individual pod weight (10.7g) was noted with fresh Moringa leaves extract solution. Among the various levels of MLE solution, maximum individual pod weight (12.0g) was noted with 6% extract of Moringa leaves, followed by 8% with 11.6g individual pod weight, while minimum (9.6g) individual pod weight was noted in control.

With dry Moringa leaves powder solution maximum individual pod weight was obtained because it also produced okra fruit with maximum length and diameter. Ragab (2002) reported that Ascorbates is the rich source of flavonoids and carotenoids that are present in Moringa leaves improves enhancement of fruit size and fruit juice contents. Moringa leaf extract also contains different plant growth regulators which improves fruit diameter by increasing cell number and enlargement. Nasir *et al.* (2020) stated that Moringa leaf extract (MLE) at 3% on mandarin tree significantly enhanced individual fruit weight and marketable fruit percentage. Hala *et al.* (2017) reported that *Capsicum annum* in response to Moringa leaf extract gave maximum fruit volume and fruit mass as compared with control. Same results was noted by Abdelnaser *et al.* (2017) and Yasmeen *et al.* (2014) in snap bean and tomato crop.

#### Pods plant<sup>-1</sup>

Significant response was noted on pods per plant with the influence of solution application forms and levels of Moringa leaf extract, while non-significant response was noted in case of interaction (Table 2). Plants with maximum pods (34.5) were recorded with dry Moringa leaves powder solution, while plants with least pods (33.7) were produced with fresh Moringa leaves extract solution. According to different levels of MLE solution, 6% MLE solution produced increased pods per plant (36.3) which was followed by 8% (35.3) of Moringa leaf extract (MLE) solution, while lowest (31.7) pods plant<sup>-1</sup> were noted in control.

It has been reported that dry leaves has high phytochemicals and antioxidants compounds as compare to fresh leaves (Ayodele *et al.*, 2015). Hence extracts with maximum phytochemicals and antioxidants compounds provide best protection to the plants from invading pathogens and insects and plant remains healthy and produce maximum fruits

according to its potential. Dry Moringa leaf extract contain more minerals contents (K, Ca, P, Mg) and PGRs such as Cytokinin, Auxin, antioxidants and phenolic compounds which has mechanism to control ovary abscission and increase fruit set (Talon and Zeevaart, 1992). Moringa leaf extract (MLE) spray on Okra increased no. of pods up to 70% as compared with control treatment (Ozobia, 2014). Extract of Moringa leaves as a foliar spray on *Capsicum* produced best results in terms of yield attributes (Hala *et al.*, 2017). According to Nasir *et al.* (2020) Moringa leaf extract (MLE) application at 3% on mandarin tree at premature stage showed significant effect on fruit numbers.

#### Yield ha<sup>-1</sup> (tons)

Significant response was noted on yield per hectare with the influence of solution application forms and levels of Moringa leaf extract, while non-significant response was noted in case of interaction (Table 2). The highest yield ha<sup>-1</sup> (14.6 tons) was noted with dry Moringa leaves powder solution, while low yield ha<sup>-1</sup> (13.5tons) was noted in fresh Moringa leaves extract solution. Regarding different levels of Moringa leaf extract (MLE) solution, mean table showed that increased (16.4tons) yield ha<sup>-1</sup> was noted with 6% Moringa leaf extract (MLE) solution which was followed by 8% (15.4tons), while lowest (11.3 tons) yield ha<sup>-1</sup> was noted in untreated plots.

Dry Moringa leaves powder solution produced different results because both has different nutrient status. Vaidya *et al.* (2014) reported that there was significant variation in dry and fresh leaves extract in term of antioxidant compounds. Increase in yield ha<sup>-1</sup> due to dry Moringa powder extract solution is because it also produced maximum yield plot<sup>-1</sup>. According to Makkar *et al.* (2007) sufficient amount of Cytokinin (Zeatin and Kinetin), micro (Fe and Zn) and macro-elements (P, K and Mg), Ascorbates, minerals, and amino acids are present in Moringa tree leaf which plays important role in fruit production. Moringa leaf extract (MLE) promoted growth of plant seedlings, plant strength against pest and diseases, decrease leaf abscission, promote root growth, increase size of the fruits which leads to higher production about 20-30% (Fuglie, 2000). Same findings were also published by (Yasmeen *et al.*, 2013a; Khan *et al.*, 2017b; Nasir *et al.*, 2020) in common bean, wheat and Kinnow.

## Conclusions and Recommendations

It has been concluded from the findings of the current study that both Moringa leaf extracts levels and its forms significantly improved both vegetative and reproductive attributes of okra. Dry Moringa leaf extract solution resulted in better results as compare to fresh leaf extract in term of plant height, branches plant<sup>-1</sup>, flowers plant<sup>-1</sup>, number of pickings, pod length, pod diameter, individual pod weight, pods plant<sup>-1</sup>, yield ha<sup>-1</sup> and days to first picking. Among levels, 6% of Moringa leaf extract (MLE) solution resulted in maximum branches plant<sup>-1</sup>, flowers plant<sup>-1</sup>, pods plant<sup>-1</sup>, pod length, pod diameter, individual pod weight, yield plot<sup>-1</sup> and yield ha<sup>-1</sup>. Therefore, it has been recommended that dry Moringa leaf powder extract solution at 6% may be used for improved growth and yield of okra crop under Swat climate.

## Novelty Statement

The current study is novel because for the first time research has been done on the solution application forms of Moringa. Current study will provide information to apply Moringa in its most effective solution form and concentration.

## Author's Contribution

**Wajid Ali and Muhammad Noman Khan:** Conceived and designed the experiment.

**Wajid Ali and Muhammad Noman Khan:** Performed the experiment.

**Wajid Ali and Ghulam Nabi and Saira Sattar:** Analyzed the data.

**Muhammad Fawad Khan, Shahid Ur Rahman, Qurat Ul Ain, Saeed Ur Rahman, Syed Zubair, Muhammad Sabeeh and Afsar Ali:** Contributed reagents, materials, analysis tools.

**Wajid Ali and Muhammad Noman Khan:** Wrote the paper.

## Conflict of interest

The authors have declared no conflict of interest.

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