Probing profitability of irrigated and rainfed bread wheat (*Triticum aestivum* L.) crops under foliage applied sorghum and moringa extracts in Pakistan

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Abstract

The increasing prices of farm inputs and declining crops productivity lead to decreased economic returns resulting in switching from staple to cash crops which can be ill-afforded if the food security of masses is to be ensured. This field trial aimed to increase the profit of irrigated and rainfed wheat (cv. NARC-2009) crops through foliage applied moringa leaf extract (MLE) and sorghum water extract (SWE). Foliar spraying of MLE and SWE in 1 and 2% concentration (v/v) was done at 22, 40 and 55 days after sowing of the wheat crops. Irrigated wheat under foliage applied 2% MLE recorded the highest gross income (US$ 893 and 924 in 2011-12 and 2012-13 respectively) and net income (US$ 439 and 450 in 2011-12 and 2012-13 respectively) owing to higher economic yields which led to the maximum benefit-cost ratio (BCR) (1.97 and 1.95 in 2011-12 and 2012-13 respectively). MLE in either concentration was also effective in boosting the profitability of rainfed wheat while, the foliar sprays of SWE in 2% concentration resulted in the lowest net income (US$ 70 and 83 in 2011-12 and 2012-13 respectively) and BCR (1.16 and 1.18 in 2011-12 and 2012-13 respectively). There is a dire need to carry out further investigations to optimize the concentration and number of foliar sprays along with the time and stage of foliar applications of allelopathic water extracts for boosting wheat yield under rainfed and irrigated conditions.

Keywords: Allelopathy. Benefit-cost ratio. Economic turn out. Exogenous application. Zeatin.

1. Introduction

Economic returns occupy vital place in all agri-businesses including crops production under varying agro-environmental conditions. The on-farm profitability serves as one of the most crucial factors in the stabilization, continuity and advancement of farming operations (Freitas *et al.*, 2015). Even a slight decline in marginal returns leads to crops switching and cash crops cannot be allowed to replace staple crops for want of high economic gains. Skyrocketing prices of inputs have multiplied the cost of production of staple crops while poor marketing conditions have made the situation from bad to worse in developing countries like Pakistan, India, Bangladesh, Iran and many Central Asian States (Iqbal *et al.*, 2016). Thus the only option left behind is to raise the productivity of staple crops for increasing the profit of farmers.

Bread wheat or common wheat (*Triticum aestivum* L.) is the staple food of hundreds of million masses across the globe. It is one of the most important members of family *Poaceae* or *Gramineae* and tribe *Triticeae* (Iqbal *et al*., 2015). Its origin is thought to be the Western Asia from where it spread to other parts of world (Zhang *et al*., 2010). Wheat (713 million tons) is the third most produced cereal globally after maize (1016 million tons) and rice (745 million tons) (Afzal *et al*., 2015; Meena *et al*., 2013). Wheat accounts for 9.6 percent of the value added in agriculture and 1.9 percent of GDP of Pakistan. There were 9 million hectares under wheat crop with the production of 25.6 million tons (Economic Survey of Pakistan, 2016-17).

Serious efforts are underway to economize the use of macro and micro nutrients along with plant growth regulators (PGRs) for field crops in order to increase profitability by reducing the cost of production and increasing economic yields (Abbas *et al*. 2015; Iqbal, 2014a). The foliage applied micro-nutrients and PGRs have been reported to increase the overall performance of many cereal crops by providing optimum nourishment while minimizing the nutrient losses from the field (Buchi *et al*. 2016; Afzal and Iqbal, 2015; Zhang *et al*. 2010). Furthermore due to the high prices of chemical fertilizers, integrating natural resources of macro and micro nutrients like allelopathic water extracts with conventional fertilization regimes carry a broad scope (Iqbal *et al*., 2013; Iqbal *et al*., 2014). The leaves of moringa (*Moringa oleifera* Lam.) have been reported to be rich in cytokinin, various minerals, phyto-hormones and inorganic salts (Merwad and Abdel-Fattah, 2017) which have the potential to increase the economic gains by increasing crops productivity. Similarly, foliar application of sorghum (*Sorghum bicolor* L.) water extract also referred to as "Sorgaab" (Cheema *et al*., 2004) may have negative or growth promoting impact on the productivity and the profitability of rainfed and irrigated wheat crops.

There is a serious lack of field investigations regarding economics of production of irrigated and rainfed wheat crops under foliage applied moringa and sorghum water extracts. Thus, this study was aimed to assess the impact of different concentrations of moringa leaf extract and sorghum water extract on the profitability (gross income, net income and the benefit-cost ratio) of irrigated and rainfed wheat crops.

2. Literature Review

The profitability of many crops has been reported to be increased (US$ 150-600 ha^{-1}) with foliar application of growth promoting hormones (PGRs) (Iqbal, 2014). PGRs applied in conjunction with micro-nutrients were effective in increasing crops yield by 17-39% which led to an increase of 5-13% in the net income. In addition, the benefit-cost ratio (BCR) under foliage applied PGRs was found to be in the range of 1.15-3.95, indicating a reasonably appropriate advantage over control treatment (Afzal and Iqbal, 2015; Yasmeen *et al*. 2011). MLE applied as seed invigoration technique improved the germination and seedling growth of sunflower and ultimately enhanced the nutrient use efficiency which led to significantly higher economic returns (Abbas *et al.,* 2015). Three foliar sprays of MLE increased grain and stover yield of maize and ultimately generated 11% higher profit as compared to the control treatment. The presence of growth promoting hormone (zeatin) was described as the possible factor behind the higher economic returns generated by the exogenous application of MLE (Shehu and Okafor, 2017).

Foliage applied MLE in 0.5% concentration (v/v) was found to be an economical approach as it resulted in significantly higher gross and net income of canola owing to higher grain yield with comparatively lesser additional expenditures (Iqbal, 2015). Nawaz *et al.* (2016) reported that foliage applied moringa leaf extract (MLE) was the most cost-effective strategy for increasing the economic returns (US$ 761) and the benefit-cost ratio (BCR) (2.26) of wheat under moisture limited conditions. Similarly, foliar application of MLE increased the nutrient use efficiency of okra under organic manuring regimes by recording 46% higher land-equivalent ratio, while the increment in the net profit was 21% (Ozobia *et al.*, 2014). Furthermore, it was reported that seed priming and exogenous application of 3% MLE remained unmatched by generating the net income of US$ 735, while the BCR (1.71) was also the highest compared to other treatments (Bakhtavar *et al.*, 2015).

For any technology, product and process to become successful, it must be cost-effective otherwise it would not be adaptable on larger scale. MLE applied in conjunction with humic acid recorded the highest benefit-cost ratio (BCR) (2.47) and thus justified itself as an economical approach to enhance economic returns (Prabhu *et al.*, 2009). The combined application of MLE and sorghum water extract (3% concentration) increased the profitability of maize crop under irrigated conditions (Kamran *et al.*, 2016). Abo Al-Enien *et al.* (2015) reported that the exogenous application of MLE in 3% concentration (v/v) was found to be one of the most economical strategies to supply essential nutrients and vitamins to plants and trees for enhancing the economic yields and net benefits. Similarly, the seed priming of wheat with MLE gave US$ 226 h^{-1} higher than the control treatment, while BCR was also increased (2.20) (Nawaz *et al.*, 2017). However, the growth promoting impact of sorghum water extract remains an unexplored aspect along with the dose optimization of MLE for irrigated and rainfed wheat crops under agro-climatic conditions of Pakistan.

3. Materials and Methods

The research trial was conducted at the agronomic research farms of the University of Agriculture Faisalabad (Pakistan) (30.35-31.47°N and 72.08-73.0°E with an altitude of 184.5 m) (Iqbal *et al*. 2014a) during the winter seasons of 2011-2012 and 2012-2013. Pre-sowing physico-chemical analysis of experimental site was done by preparing thee composite soil samples from sub-samples taken from four corners and middle of the experimental blocks up to the depth of 15-30 cm (Table 1).

Table 1: Physico-chemical properties of the experimental soil (Faisalabad, Pakistan) determined from soil samples taken from 15-30 cm depth before sowing of irrigated and rainfed wheat crops during 2011-12 and 2012-13.

Soil characteristics	Observations	
Mechanical analysis	**2011-2012**	**2012-2013**
Sand (%)	53	55
Silt (%)	24	23
Clay (%)	23	22
Textural class	Sandy clay loam	Sandy clay loam
Chemical analysis	**2011-2012**	**2012-2013**
pH	7.4	7.1
Electrical conductivity (dSm^{-1})	1.81	1.74
Organic matter (%)	0.83	0.74
Total nitrogen (mg kg^{-1})	386.0	369.9
Available phosphorous (mg kg^{-1})	9.7	8.4
Available potassium (mg kg^{-1})	186.4	197.6

Metrological data for temperature, relative humidity and rainfall during growing seasons of wheat were obtained from a meteorological observatory located around 1 km away from the experimental area (Figure 1).

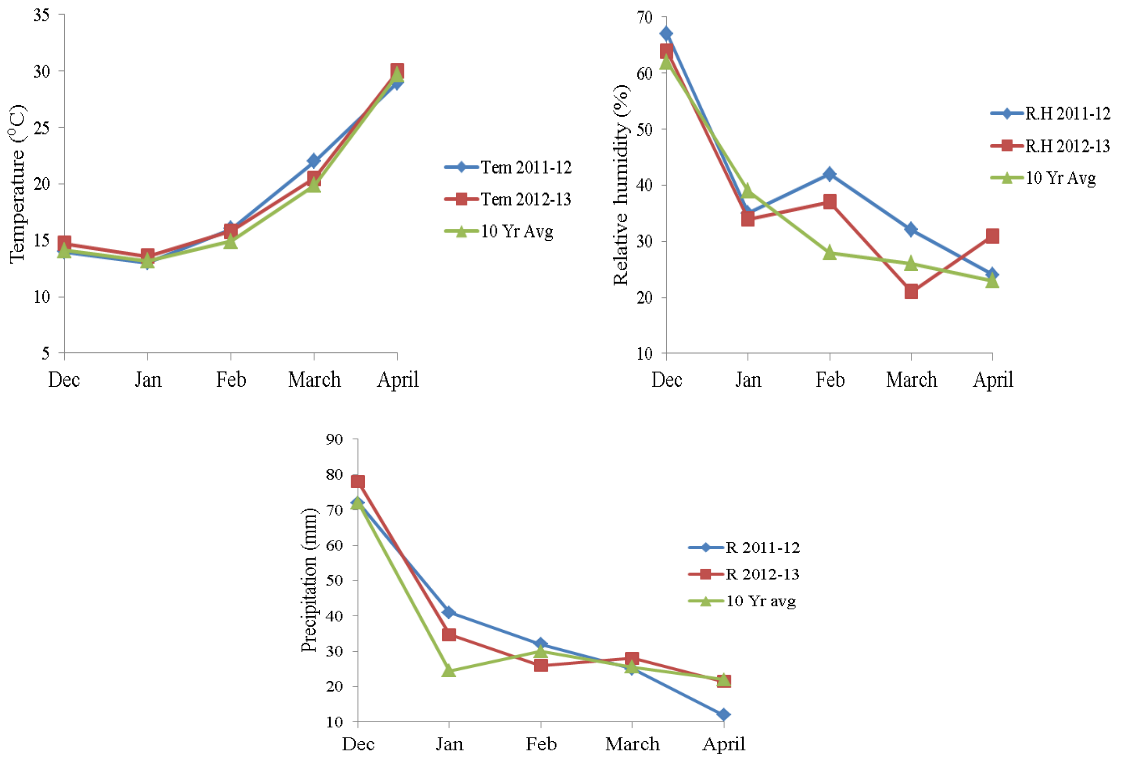

Figure 1: Meteorological data (temperature, relative humidity and precipitation) for wheat growing seasons during 2011-12 and 2012-13 at Faisalabad Pakistan.

The treatments included two factors;

Factor A (Foliar applications)

Foliar application of 1% moringa leaf extract (MLE)

Foliar application of 2% moringa leaf extract (MLE)

Foliar application of 1% sorghum water extract (SWE)

Foliar application of 2% sorghum water extract (SWE)

Factor B (Crop condition)

Irrigated wheat crop

Rainfed wheat crop

There were eight treatments in total that were replicated thrice. Foliar application of moringa and sorghum water extracts was performed at 22, 40 and 55 days after sowing of both irrigated and rainfed wheat crops. The experiment was laid out in a factorial arrangement of randomized complete block design (RCBD) with four replicates. The net plot size was maintained at 7.2 m x 15.0 m (32 lines per plot).

Wheat (cv. NARC-2009) was sown on a fine seed bed (prepared by 3 cultivations each followed by a planking) in 22.5 cm spaced rows using a single row hand drill on November 14, 2011 and November 10, 2012. The seed rate of wheat was 145 kg ha^{-1} for both irrigated and rainfed crops. N:P:K were applied as urea, di-ammonium phosphate and potassium sulfate at the rate of 120:85:60 kg ha^{-1} respectively. Half of the nitrogen and full dose of phosphorous and potassium were applied at the time of sowing, while the remaining half nitrogen was applied in two equal splits with subsequent flood irrigations of 7.5 cm each at 22 and 40 days after sowing. For rainfed wheat crop, the recommended doses of N, P and K were applied as a basal dose at the time of sowing.

3.1. Preparation of allelopathic water extract of sorghum

Allelopathic water extracts of sorghum locally called as “Sorgaab” were prepared by following the methodology of Cheema and Khaliq (2000). Herbage (stem and leaves) of freshly harvested sorghum plants at maturity were separated and subsequently shade dried for few days. Shade dried herbage was then chopped down into 2 cm pieces with the help of an electric fodder cutter. This chopped material was soaked in water in 1: 10 (w/v) ratio for 24 hours. Water extract was collected by passing through sieves. Filtrate was boiled at 100 °C in order to reduce the volume up to 20 times. Sorgaab was stored at room temperature for subsequent use.

3.2. Moringa leaf extracts preparation

Moringa leaf extract (MLE) was prepared by collecting young leaves of moringa trees at the nursery of Department of Forestry and Rangeland, University of Agriculture Faisalabad. The collected leaves were washed and sterilized before being frozen in a refrigerator for two days. After that leaves were grounded in a manual juicer. The juice was collected and filtered by passing through a muslin cloth to remove all residues and the green matter. Solutions of 1 and 2% (v/v) were prepared stored at room temperature for subsequent use.

Both moringa leaf extract and sorghum water extract solutions were then applied at 20, 35 and 50 days after sowing. All the foliar applications were done by using a knap sack hand sprayer fitted with a flat fan nozzle. Calibration was done by foliage applied water. All the agronomic practices were kept the same and uniform for all the treatments.

3.3. Economic analyses

For calculating the gross income, net income and the benefit to cost ratio, data were subjected to economic analysis by following the methodologies outlined by CIMMYT (1988). The fixed costs such as labor, seed cost, land rent, cultivation charges, manual hoeing, harvesting, transportation and local markup of 8% on investment) and variable costs (tube-well irrigations cost and foliar applications) were summed-up under the head of total expenditures (Te).

$$Te = \text{Fixed costs} + \text{variable costs} \quad (1)$$

The gross income (Gi) earned from rainfed and irrigated wheat under foliage applied moringa and sorghum water extracts was calculated as:

$$Gi = WEY \times Rlm \quad (2)$$

Where, WEY and Rlm represent wheat economic yield and rate of wheat in local market respectively.

This gross income was further used to calculate the net income (Ni) in the following way;

$$Ni = Gi - Te \quad (3)$$

Where, Gi and Te are the same as calculated in equations 2 and 1 respectively.

The benefit to cost ratio (BCR) was computed as;

BCR = Gi / Te

(4)

Here, Gi and Te represent gross income and total expenditures respectively which are the same as in equations 2 and 1.

3.4. Statistical analysis

For data regarding economic yield of wheat, an analysis of variance technique was employed with the help of 'MSTAT-C' software package. Differences among the treatment means were compared and separated using the Duncan's multiple range test at 5% probability level (Freed and Eisensmith, 1986).

4. Results and Discussion

Profit occupies central place in farming and all other agri-businesses. To halt the crop switching from staple to cash crops, the economic returns need to be at least maintained, if not increased. The irrigated wheat remained outstanding to rainfed crop especially under foliar application of 2% moringa leaf extract (MLE) as it recorded the highest gross income (US$ 893 and 924 in 2011-12 and 2012-13 respectively) and net income (US$ 439 and 450 in 2011-12 and 2012-13 respectively). The irrigated wheat under foliage applied 1% MLE followed it with gross income of US$ 840 and 871 in 2011-12 and 2012-13 respectively, while the net income was US$ 387 and 397 in 2011-12 and 2012-13 respectively. The lowest gross income (US$ 508 and 541 in 2011-12 and 2012-13 respectively) and net income (US$ 70 and 83 in 2011-12 and 2012-13 respectively) were recorded for rainfed wheat under foliar application of 2% SWE (Table 2 & 3).

Table 2: Economic analyses of irrigated and rainfed wheat crops under foliar applications of 1% and 2% moringa leaf extract (MLE) and sorghum water extract (SWE) during 2011-12.

Treatments	Gy (t ha^{-1})	Te (US$)	Gi (US$)	Ni (US$)	BCR
Irrigated wheat under 1% MLE foliar application	3.54±0.23b	453.75	840.75	387.00	1.85

Irrigated wheat under 2% MLE foliar application	3.76±0.12a	453.75	893.00	439.25	1.97
Rainfed wheat under 1% MLE foliar application	2.41±0.26de	438.50	572.37	133.87	1.30
Rainfed wheat under 2% MLE foliar application	2.49±0.12d	438.50	591.38	152.88	1.35
Irrigated wheat under 1% SWE foliar application	3.19±0.67c	453.75	757.62	303.87	1.67
Irrigated wheat under 2% SWE foliar application	3.09±0.17cd	453.75	714.63	260.88	1.58
Rainfed wheat under 1% SWE foliar application	2.29±0.64e	438.50	543.87	105.37	1.24
Rainfed wheat under 2% SWE foliar application	2.14±0.17f	438.50	508.25	69.75	1.16

Te = total expenditures, Gi = gross income, Ni = net income, BCR = benefit-cost ratio, US$ = US dollars, market rate of wheat = USD 237.5 ton^{-1}.

The benefit-cost ratio (BCR) which depicts the profit earned for additional expenditures was observed to be the highest for irrigated wheat under foliar application of 2% MLE (1.97 and 1.95 in 2011-12 and 2012-13 respectively), while it was followed by 1% MLE foliar sprayed on irrigated wheat (1.85 and 1.83 in 2011-12 and 2012-13 respectively). Rainfed wheat was also found to be responsive to foliage application MLE, but it remained below par to irrigated wheat. The rainfed wheat under foliage applied 2% SWE resulted in the minimum BCRs of 1.16 and 1.18 in 2011-12 and 2012-13 respectively (Table 2 & 3).

Table 3: Economic analyses of irrigated and rainfed wheat crops under foliar applications of 1% and 2% moringa leaf extract (MLE) and sorghum water extract (SWE) during 2012-13.

Treatments	Gy (t ha^{-1})	Te (US$)	Gi (US$)	Ni (US$)	BCR
Irrigated wheat under 1% MLE foliar application	3.67±0.23b	473.75	871.62	397.87	1.83
Irrigated wheat under 2% MLE foliar application	3.89±0.12a	473.75	923.87	450.12	1.95
Rainfed wheat under 1% MLE foliar application	2.56±0.26d	458.50	608.50	149.5	1.32
Rainfed wheat under 2% MLE foliar application	2.61±0.12cd	458.50	619.87	161.37	1.35
Irrigated wheat under 1% SWE foliar application	3.31±0.67c	473.75	768.12	312.37	1.62
Irrigated wheat under 2% SWE foliar application	3.28±0.17c	473.75	779.00	305.25	1.64
Rainfed wheat under 1% SWE foliar application	2.34±0.64de	458.50	555.75	97.25	1.21

Rainfed wheat under 2% SWE foliar application	2.28±0.17e	458.50	541.50	83.00	1.18

Te = total expenditures, Gi = gross income, Ni = net income, BCR = benefit-cost ratio, US$ = US dollars, market rate of wheat = USD 237.5 ton^{-1}.

The wheat crop under irrigated conditions with foliar application of 2% MLE recorded the highest grain yield and ultimately it gave the maximum gross income. This treatment did not incur addition expenditures than other foliar applications of SWE which resulted in significantly higher net income owing to lesser costs. Significantly lower grain yield of wheat under 1% and 2% sorghum water extract (SWE) as depicted in Tables 2 and 3, not only decreased the gross and net incomes but the benefit-cost ratio was also decreased. Similar findings were reported by Iqbal *et al*. (2015), who concluded that SWE also referred to as sorgaab was instrumental in reducing the growth and density of weeds in wheat crop which reduced the cost of production owing to fewer use of herbicides. In this way, profitability was increased owing to reduction in variable cost of herbicides use, not owing to the increase in economic yield. However, contrary to our findings, no reduction in economic gains due to reduced productivity was observed (Mubeen *et al.,* 2012; Lashari *et al.,* 2008). Similarly, MLE applied in 0.5% concentration was also found effective in boosting wheat yield and ultimately a significant increase in the net income and marginal rate of return was recorded (Hossain *et al.,* 2012; Iqbal *et al.,* 2009). In addition, three foliar sprays of MLE in 1% concentration were instrumental in recording the highest benefit-cost ratio (BCR) in comparison with costly synthetic plant growth regulators (Phiri and Mbeve, 2010).

5. Conclusions

It was hypothesized that foliage spraying of moringa leaf extract (MLE) and sorghum water extract (SWE) have the potential to increase the economic turn outs of wheat under irrigated and rainfed conditions. Our hypothesis proved true partially as foliage applied MLE increased the net income along with the benefit-cost ratio owing to increased economic yield of irrigated and rainfed wheat especially when applied in 2% concentration. However, SWE was not effective in increasing the economic gains rather its higher concentration led to a sharp decline in the profitability of both irrigated and rainfed wheat crops. These finding in themselves acknowledge for not being definitive and call for more in-depth evaluations of different concentrations (3, 4, 5% etc.) of MLE. Furthermore, lower concentrations of SWE may also be tested to develop these allelopthaic water extracts as a plant nutrients supplements in an economical way and ultimately to increase the economic gains of wheat growers under rainfed and irrigated conditions.

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