

Bio-economic viability of rainfed wheat (*Triticum aestivum* L.) cultivars under integrated fertilization regimes in Pakistan

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Abstract

To ensure the food security of rising human population, proportionate increase in yields of staple crops like wheat takes central place. To promote sustainable wheat cropping systems having the minimum environmental hazards and the maximum economic turn outs, source and dose optimization of organic wastes for specific cultivars occupies pivotal position. This field study investigated the response of rainfed wheat cultivars (NARC-2009 and Pakistan-2013) to different fertilization regimes involving two organic materials (poultry litter and farm yard manure) applied solely (12.5 and 20 tons ha⁻¹ respectively) and in conjunction with reduced doses of organic manures (50% of solo application on weight basis) and chemical fertilizers (50% of solo application on weight basis). The grain yield (Gy), biological yield (By), harvest index (Hi) and economic indicators were recorded as response variables. NARC-2009 under sole application of Cf remained unmatched in term of Gy (4.32 t ha⁻¹), By (9.85 t ha⁻¹) and Hi (44%). The same cultivar under binary application of poultry litter+50% fertilizers followed it with Gy of 4.08 t ha⁻¹, which in turn was followed by combined application of farm yard manure+50% fertilizers. The solo application of chemical fertilizers incurred the highest cost (US\$ 519) and also generated the highest net earnings (US\$ 560)

along with the value-cost and benefit-cost ratios, while it was followed by co-application of poultry litter and reduced doses of chemical fertilizers. To conclude with, the grain yield potential of wheat cultivars differed significantly, while binary application of poultry litter and reduced doses of chemical fertilizers have the potential to yield comparatively better wheat grain yield and economic turn outs under rainfed conditions, although those were not comparable to solo application of inorganic fertilizers.

Keywords: Benefit-cost ratio. Biological yield. Economic analysis. Poultry manure. value-cost ratio.

1. Introduction

Environmental pollution triggered by nitrate leaching and emissions of nitrous oxide along with decreasing profitability owing to expensive chemical fertilizers have become serious concerns under changing climatic conditions (Iqbal *et al.*, 2018). Biologically unviable disposal of organic wastes of dairy and poultry farms is disturbing agro-ecological balances. Despite extensive use of chemical fertilizers, wheat (*Triticum aestivum* L.) yield and revenue generation from this staple crop have been consistently below par in Indo-Pak sub-continent and many Central Asian states (Iqbal *et al.*, 2015; Mahmood *et al.*, 2017) owing to unavailability of high yielding cultivars (Afzal *et al.*, 2015), scarcity of irrigation water at critical growth stages, lack of balanced nutrients (Wen *et al.*, 2016) and reduced soil fertility (Zhao *et al.*, 2016). Due to wide-scale utilization of inorganic fertilizers, their prices have skyrocketed in recent years making them unaffordable to the farmers having small land holding especially in developing countries of South Asia (Leghari *et al.*, 2016). In addition, the side-effects of chemical fertilizers have become evident in the form of eutrophication and contamination of surface and ground water (Afzal & Iqbal, 2015; Omara *et al.*, 2017).

Organic materials have the potential to serve as an alternate source of plant nutrients but comparatively lesser yields and economic turn outs under organic manuring regimes constitute the biggest hurdles in way of adopting organic materials as a conventional fertilization source (Yang *et al.*, 2015). On the other hand, the richness in easily available nutrients, covering lesser area, convenient transportation and easier application and higher productivity make chemical fertilizers superior, preferable and profitable (Sarwar *et al.*, 2011) in comparison to organic manures. However, the combined application of organic manures with synthetic fertilizers may provide better yields and revenue from cereals even higher than chemical fertilizers (Sarwar *et al.*, 2007). In the sub-Himalayan region, soil is poor in organic

matter (0.65-1.50%) and the addition of organic fertilizers and composts can give optimal crop yields in the long run along with boosting the soil health, organic matter nutrient uptake and subsequent economic turn outs (Khaliq *et al.*, 2017).

However to maintain yields and profitability of intensive cropping systems, the use of chemical fertilizers cannot be eliminated but organic manures applied in conjunction with reduced doses of chemical fertilizers might lead to more sustainable wheat cropping system. The binary application of urea (160 kg ha⁻¹) and compost (30 Mg ha⁻¹) recorded the highest grain yield of wheat than sole application of chemical fertilizers under tropical conditions (Abedi *et al.*, 2010). Similarly, Tahir *et al.* (2011) reported that wheat yield was increased by 19% when two-third of recommended dose of NPK was applied in amalgamation with the composted organic materials of animal origin (cattle and buffalo farm yard slurry) which increased the economic turn outs. Furthermore, organic compost (0.65 t ha⁻¹) and reduced doses of chemical fertilizers positively affected physico-chemical properties of the soil and improved the yield attributes and economic yield of wheat along with generating the highest monetary returns (Muhammad *et al.*, 2013). However, organic manures performed differently under varying agro-climatic conditions (Wen *et al.*, 2016) which necessitates testing of organic materials under local conditions before recommending these for wide scale adaption.

Reliable experimental evidences are scant regarding wheat cultivars response to integrated fertilization regimes under agro-environmental conditions of sub-Himalayan region. Thus, our hypothesis was that organic manures applied in conjunction with chemical fertilizers and binary application of two organic manures might result in higher yield of wheat than solo application of organic materials or chemical fertilizers. The objective of this field investigation was to assess the comparative performance of wheat cultivars under integrated fertilization regimes and to optimize the dose of organic and inorganic fertilizers applied solely and in different combinations for boosting wheat yield and economic turn outs.

2. Literature Review

Without determining the economic viability of organic manures, no solid recommendations can be formulated and forwarded for wide scale adoption in order to promote their utilization in crop production. Omara *et al.* (2017) reported that integrated fertilization regimes were found to be economically and biologically viable compared to solo application of chemical fertilizers or organic manures.

The integration of organic manures with chemical fertilizers could be effective in elevating economic turn outs along with reducing the imbalanced use of fertilizers which continues to remain an important issue in agriculture while integrated fertilizers regimes could serve an alternate option for boosting production, net income and benefit-cost ratio of field crops along with assisting in gradual build-up of the soil fertility (Gupta *et al.*, 2006).

Ram and Mir (2006) concluded that winter wheat was quite responsive to co-application of organic materials and mineral fertilizers; however it was stressed to investigate organic manures of different origins including plant materials, animal wastes, bio-fertilizers, vermicompost to reduce the cost of production and increase profits.

Similarly, it was reported that use of farm yard manure for wheat production resulted in 60% higher cost of production of wheat compared to control, while co-application of farm yard manure and rice residues increases cost of production by 55%. In comparison to control treatment, vermicompost applied in conjunction with rice residues increased cost of production by 43%, while co-application of vermicompost, rice residues and inoculation of bio-fertilizers remained the cheapest option among the integrated fertilization regimes.

The solo application of farm yard manure gave the highest net income and it was closely followed by sole application of vermicompost as far as profitability was concerned (Davari *et al.*, 2012). Similarly, it was reported that integrated application of farm yard manure and nitrogen fertilizer was instrumental in generating the highest net income owing to better yield and significantly lower cost of production compared to other organic manures (Singh and Agarwal, 2006).

Pathak *et al.* (2002) recorded that farm yard manure applied in conjunction with 75% of recommended chemical fertilizers remained unmatched for generating the highest profitability and the lowest cost of production along with the maximum benefit-cost ratio. In contrast, Behera *et al.* (2007) concluded that integrated application of farm yard manure, poultry manure and NPK fertilizers recorded the highest net income as well as benefit-cost ratio compared to solo application of farm yard manure and poultry litter and thus recommended to use these organic manures in conjunction with reduced doses of chemical fertilizers to obtain the maximum profit.

However, Kumar and Shiva (2010) reported that farm yard manure equivalent to 60 kg N per hectare applied in conjunction with cowpea manure and azotobacter remained unmatched by yielding the highest net earnings compared to solo application of organic manures. Thus, integrated application of organic manures and chemical fertilizers generated

significantly higher net income mainly by reducing cost of production and increasing economic yield of wheat under irrigated as well as rainfed conditions.

3. Materials and Methods

The experiment was carried out at the student farm of Department of Agronomy, Faculty of Agriculture, The University of Poonch Rawalakot (AJK), Pakistan (33° 51' to 33° 85' °N and 73° 48' to 73° 80' °E with an altitude of 1640 meters), for three consecutive years during autumn seasons of 2014-15 to 2016-17. The climate of the area is classified as tropical with an average annual precipitation of 800-1400 mm mainly concentrated during the months of May-August, while mean daily temperature ranges 10-23 °C (Khaliq *et al.*, 2017). The pre-sowing physico-chemical analyses of the experimental blocks were performed by taking representative soil samples from four corners and middle of the field up to a depth of 30 cm. These representative samples were homogeneously mixed to form the composite samples which were subsequently analyzed. The textural class of the soil was sandy loam and was deficient in organic matter and primary nutrients.

Treatments included three sources of plant nutrients including farm yard manure (Fym) (20 tons ha⁻¹), poultry manure (Pl) (12.5 tons ha⁻¹) and the NPK (Cf) (120:100:80 kg ha⁻¹). In this way, the experiment was comprised of following seven fertilization combinations; T₀= control, T₁= Solo chemical fertilizer (Cf), T₂= solo farm yard manure (Fym), T₃= solo poultry litter (Pl), T₄= poultry litter + farm yard manure (Pl+Fym), T₅= poultry litter + chemical fertilizers (Pl+Cf), T₆= chemical fertilizers + farm yard manure (Cf+Fym). Two wheat varieties (NARC-2009 and Pakistan-2013) were also used as an experimental material having the seed rate of 120 kg ha⁻¹. In this way, there were fourteen treatment combinations in total. The research was carried out in randomized complete block design with four replications. The net plot size was maintained at 5 × 14 m having twenty rows per plot. A distance of three meters was maintained among the replications, while the spacing among experimental plots was half a meter. All the cultural practices were done homogeneously across the experimental plots.

Biological yield was estimated by harvesting all plants of each plot and weighing them using a spring balance after threshing. Harvest index (Hi) was calculated with the help of equation 1 (Afzal *et al.*, 2015);

$$Hi (\%) = \frac{\text{Grain yield}}{\text{Total yield}} \times 100 \quad (1)$$

Biological yield

The economic analysis was performed as per below given equations.

$$Tc = Fc + Vc \quad (2)$$

Where, Tc, Fc and Vc represent total cost, fixed cost (land, labour, herbicide, harvesting and threshing) and variable cost (manures and seed) respectively.

$$Ge = Gy \times Ur \quad (3)$$

Where, Ge, Gy and Ur indicate gross earning, grain yield and unit rate of wheat grain.

$$Ne = Ge - Tc \quad (4)$$

Where, Ne, Ge and Tc represent net earnings, gross earning and total cost.

Finally benefit-cost ratio (BCR) was calculated for each treatment by following the below stated equation.

$$BCR = Ge/Tc$$

(5) Where, Ge and Tc are gross earnings and total cost which are same as described in equations 2 and 3.

Incremental earning (Ie) was calculated by following the equation 6.

$$Ie = Ay - Ca \quad (6)$$

Where, Ay indicates value of additional yield and Ca represents cost of additional inputs.

Value-cost ratio (VCR) was also calculated by following the equation 7.

$$VCR = Ie/Ca$$

(7)

Where Ie and Ca are the same as described in equation 6.

The interaction effect of year \times treatments was found to be non-significant as 3-years variances were homogeneous as demonstrated by Barlett's test ($P < 0.05$) (Steel *et al.*, 1997); ultimately year-wise data were subjected to combined statistical analysis as randomized complete block design in regular arrangement. Analysis of variance (ANOVA) technique was employed by using statistical software package of SAS (SAS Inc. 2003). Finally those interaction effects which were significant, subjected to pairwise comparison by employing Tukey's honestly significant difference (HSD).

4. Results

The interaction effect ($P<0.05$) of cultivar ($P<0.05$) and fertilization regimes ($P<0.01$) was significant however with year, it was non-significant (Tables 1). Both cultivars responded differently to solo applied chemical fertilizers (Cf), poultry litter (Pl) and farm yard manure (Fym) along with their combinations (Pl+Cf, Pl+Fym, Fym+Cf). Similarly, NARC-2009 again recorded the highest number of grains per plant and 1000-grains weight under solo application of Cf, which led to the highest grain yield (4.32 t ha^{-1}), biological yield (9.85 t ha^{-1}) and harvest index (44%) (Table 1). The same cultivar under binary application of Pl+Cf closely followed the grain yield and biological yield of 4.08 and 9.31 t ha^{-1} recorded by solo Cf, which was followed by combined application of Fym+Cf, while Pakistan-2013 cultivar could not perform at par to NARC-2009 under all fertilization regimes.

Table 1: Grain yield, biological yield and harvest index of rainfed wheat cultivars under integrated fertilization regimes at Rawalakot (AJK), Pakistan.

Treatments	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V ₁ T ₀	3.24 ^l	7.32 ^j	37.59 ^f
V ₁ T ₁	4.32 ^a	9.85 ^a	43.96 ^a
V ₁ T ₂	3.40 ^g	8.15 ^g	34.55 ^e
V ₁ T ₃	3.51 ^{ef}	8.44 ^f	35.60 ^{de}
V ₁ T ₄	3.91 ^c	9.03 ^h	38.96 ^c
V ₁ T ₅	4.08 ^b	9.31 ^b	41.79 ^b
V ₁ T ₆	3.72 ^d	8.87 ^d	36.18 ^d
V ₂ T ₀	2.94 ^k	6.78 ^l	28.69 ^h
V ₂ T ₁	3.74 ^d	8.65 ^e	36.50 ^d
V ₂ T ₂	3.15 ^j	7.13 ^k	29.42 ^h
V ₂ T ₃	3.25 ^{hi}	7.34 ^j	29.89 ^{gh}
V ₂ T ₄	3.48 ^f	7.96 ^h	32.18 ^f
V ₂ T ₅	3.56 ^e	8.24 ^g	34.32 ^e
V ₂ T ₆	3.32 ^h	7.61 ⁱ	30.93 ^{fg}
Cultivar	*	*	*
Manuring	**	**	*
Cultivar×Manuring	*	**	*
Cultivar×Manuring× Year	ns	ns	ns

Means having similar letters within the same column did not vary significantly at $P<0.05$.

*= $P < 0.05$, **= $P < 0.01$, ns= non-significant at $P < 0.05$.

V₁= Wheat cv. NARC-2009, V₂= Wheat cv. Pakistan-2013.

T₀= control, T₁= Solo chemical fertilizer, T₂= solo farm yard manure, T₃= solo poultry litter, T₄= poultry litter + farm yard manure, T₅= poultry litter + chemical fertilizers, T₆= chemical fertilizers + farm yard manure

The economic analysis revealed that solo chemical fertilizers incurred the highest total cost, while the same treatment also resulted in the highest gross and net earnings (US\$ 1080 and 560 respectively) (Table 2). The highest benefit-cost ratio (BCR) was also recorded by the same fertilization regime. It was followed by co-application of poultry litter and chemical fertilizers in terms of net earnings and benefit-cost ratio, along with the combined application of poultry litter and farm yard manure. The solo application of Fym gave sub-optimal results as far as net earnings and benefit-cost ratio were concerned, however it remained superior to control treatment.

Table 2: Economic analyses of rainfed wheat cultivars under integrated fertilization regimes at Rawalakot (AJK), Pakistan.

Treatment	Total cost (US\$)	Gross earning (US\$)	Net earnings (US\$)
V ₁ T ₀	470.7	810.0	339.3
V ₁ T ₁	519.5	1080.0	560.5
V ₁ T ₂	481.1	850.0	368.9
V ₁ T ₃	490.9	877.5	386.6
V ₁ T ₄	485.0	977.5	492.5
V ₁ T ₅	513.2	1020.0	506.8
V ₁ T ₆	490.6	930.0	439.4
V ₂ T ₀	470.7	735.0	264.3
V ₂ T ₁	495.5	935.0	439.5
V ₂ T ₂	481.1	787.5	306.4
V ₂ T ₃	490.9	812.5	321.6
V ₂ T ₄	485.0	870.0	385.0
V ₂ T ₅	513.2	890.0	376.8
V ₂ T ₆	490.6	830.0	339.6

V₁= Wheat cv. NARC-2009, V₂= Wheat cv. Pakistan-2013.

T₀= control, T₁= Solo chemical fertilizer, T₂= solo farm yard manure, T₃= solo poultry litter, T₄= poultry litter + farm yard manure, T₅= poultry litter + chemical fertilizers, T₆= chemical fertilizers + farm yard manure

The solo application of chemical fertilizers resulted in the highest incremental earning (US\$ 270) as well as additional incurred cost (US\$ 48), while co-application of poultry manure and chemical fertilizers closely followed it with incremental earning and additional incurred cost of US\$ 210 and 42 respectively (Table 3). The highest value-cost ratio was recorded for integrated application of farm yard manure and chemical fertilizers which was followed by sole chemical fertilizers which in turn was followed by poultry manure applied in amalgamation with chemical fertilizers.

Table 3: Economic analyses of rainfed wheat cultivars under integrated fertilization regimes at Rawalakot (AJK), Pakistan.

Treatment	Incremental earning (US\$)	Additional incurred cost (US\$)	Value-cost ratio	Benefit-cost ratio
V ₁ T ₀	-	-	-	1.72
V ₁ T ₁	270.0	48.8	5.5	2.07
V ₁ T ₂	40.0	10.4	3.8	1.76
V ₁ T ₃	67.5	20.2	3.3	1.79
V ₁ T ₄	77.5	14.3	4.7	1.99
V ₁ T ₅	210.0	42.5	4.9	1.99
V ₁ T ₆	120.0	19.9	6.0	1.89
V ₂ T ₀	-	-	-	1.56
V ₂ T ₁	270.0	48.8	5.5	1.88
V ₂ T ₂	40.0	10.4	3.8	1.64
V ₂ T ₃	67.5	20.2	3.3	1.66
V ₂ T ₄	167.5	14.3	4.7	1.79
V ₂ T ₅	210.0	42.5	4.9	1.73
V ₂ T ₆	120.0	19.9	6.0	1.69

V₁= Wheat cv. NARC-2009, V₂= Wheat cv. Pakistan-2013.

T₀= control, T₁= Solo chemical fertilizer, T₂= solo farm yard manure, T₃= solo poultry litter, T₄= poultry litter + farm yard manure, T₅= poultry litter + chemical fertilizers, T₆= chemical fertilizers + farm yard manure

4. Discussion

Chemical fertilizers remained unmatched in terms of wheat productivity (Table 3) under rainfed conditions of sub-Himalayan region of Kashmir (Table 3 and 4). The obvious

reason is that inorganic fertilizers provide instant and ready to utilize nutrients in sufficient quantities which trigger growth and economic yield of crops (Tammeorg *et al.*, 2014). Among organic manures, poultry manure performed comparative better than farm yard manure and its performance was even boosted when applied in conjunction with reduced doses of chemical fertilizers.

Organic manures have been reported to provide nitrogen and phosphorous over a longer period of time (Meena *et al.*, 2013), while the immediate nutrient needs of plants were fulfilled by chemical fertilizers which resulted in comparatively better yield attributes like plant height, number of tillers, peduncle length, spike length and 1000-grains weight. Previously, similar findings have been reported where organic manures increased soil bulk density and water holding capacity which resulted in a significant increase in moisture content which was attributed as the major reason behind improved productivity of wheat (Abedi *et al.*, 2010; Kalleth *et al.*, 2012). These findings are also in corroboration with those of Ali *et al.* (2012) and Grutera *et al.* (2017), who reported that poultry manure and farm yard manure were rich in micro-nutrients in addition to macro-nutrients and ultimately there was a robust vegetative growth.

During reproductive growth of wheat, more assimilates were transferred to spikelets which increased the grain weight. Furthermore, the increase in the grain yield of wheat under binary application of organic materials and chemical fertilizers was reported to be 23% owing to increased activity of carboxyl and hydroxyl which increased the nutrient absorption (Hussain *et al.*, 2002; Shah *et al.*, 2011; Tahir *et al.* 2011; Zhao *et al.*, 2016). In addition, poultry manure increased soil carbon sequestration (13-24%) particularly Walkley-Black carbon and particulate organic carbon which were instrumental in boosting soil organic carbon and resultantly improved biological yield and harvest index were obtained (Kumar & Ahlawat, 2004; Ram & Mir, 2006; Buchi *et al.*, 2016).

In this experiment, farm yard manure applied solely or in combination with poultry manure or chemical fertilizers did not perform at par to other fertilization regimes (Table 4). These findings are in contradiction to Sarwar *et al.* (2007), who reported that poultry manure was less effective owing slow release of nutrients in comparison with farm yard manure which was decomposed in comparatively lesser time and supplied huge quantity of nutrients. In addition, it was also noted that shading of taller cereal plants slowed down the decomposition process of soil applied organic materials especially of poultry litter.

Furthermore, in contrast to our findings, it was noted that farm yard manure was instrumental in lowering the pH which resulted in higher nutrient absorption and ultimately significantly higher peduncle and spike lengths and 1000-grains weight led to 11% higher grain yield of wheat under irrigated conditions (Hussain *et al.*, 2008). Rainfed wheat cultivars performed differently under different fertilization regimes as NARC-2009 remained superior to Pakistan-2013 (Table 1). These finding corroborate with those of Ali *et al.* (2012) and Sarwar *et al.* (2008), who reported that different cultivars performed differently owing to their genetic potential. It was further concluded that under rainfed conditions, cultivars having drought resistance have higher nutrient use efficiency and water use efficiency and thus it was suggested to grow drought resistant cultivars in rainfed areas.

Along with biological appropriateness, the determination of economic viability occupies pivotal place in order to promote utilization of organic manures for crop production. The poultry litter applied in amalgamation with reduced doses of chemical fertilizers performed better than other fertilizer regimes in terms of net earnings, incremental earning, benefit-cost ratio and value-cost ratio, indicating a bright potential for its inclusion in crop production for boosting economic turn outs.

Hussain *et al.* (2002) also reported similar findings where poultry manure remained unmatched by generating the highest profit compared to cattle farm yard slurry and sewage sludge. In contrast, Behera *et al.* (2007) reported that integrated application of farm yard manure, poultry manure and chemical fertilizers generated the highest net income as well as benefit-cost ratio with the minimum additional incurred cost. Similarly, Pathak *et al.* (2002) also reported contradictory findings by reporting that farm yard manure applied with reduced doses of chemical fertilizers remained unmatched by generating the maximum profit and incurred the lowest additional cost.

5. Conclusions

It can be inferred that solo application of organic materials or binary application of two organic manures performed below par to chemical fertilizers as far as wheat grain and biological yields along with the economic turn outs were concerned. Organic manures applied in conjunction with 50% of chemical fertilizers remained superior to the sole application of organic materials. Among organic materials, poultry manure applied solely or in amalgamation with reduced doses of chemical fertilizers was superior to farm yard manure.

Wheat cultivars responded differently to integrated fertilization regimes as NARC-2009 performed better than Pakistan-2013 which portrait the needs to test crops cultivars under organic farming systems in order to obtain higher economic benefits.

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