Research Article

Economic Viability of Selected Soil Fertility and Soil Health Improving Technologies in Pakistan

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Abstract | Maintenance of soil fertility and improvement of soil health are indispensable to obtain better crop productivity. Various research institutions in Pakistan have developed, and promoted several technologies for sustainable soil management and to improve crop productivity. These technologies include use of micronutrients for citrus fruits and their application for off-season vegetables, use of Biozote for wheat crop, and Pak Seeder technology for sowing wheat crop by zero-till method. Keeping this in view, economic viabilities of these technologies have been determined through marginal analysis. Unfortunately, Pak-seeder technology could not be demonstrated effectively due to few institutional and technical limitations. Thus, technical issues in its manufacturing as well as its use are highlighted. The study is based on the outcomes of six demonstration sites of micronutrients' use for citrus and thirteen sites for vegetables' production in tunnels viz. chili peppers, bell peppers, cucumber and bottle gourds, twenty Biozote technology sites for wheat crop, and six Pak Seeder technology sites for planting wheat. Use of micronutrients resulted in better fruit setting and productivity in citrus by 12.5 percent and 15.0 percent, respectively. Sample farmers reported that use of the technology resulted in premium prices of the produce by ten percent. Benefit cost ratio of micronutrients use for citrus orchards was 5.71. Use of micronutrients for off-season vegetables resulted into even better gains; increased productivity of chili pepper, cucumber, bottle gourd and bell papers by 31.9, 40.6, 29.9 and 11.1 percent; with benefit cost ratios of 28.1, 17.4, 15.0 and 11.4, respectively. Similarly, application of Biozote for wheat production increased the productivity by 10.8 percent, with a benefit cost ratio of 8.2. Extensive dissemination and demonstration of these economically viable technologies for their speedy adoption is need of the hour. Similarly, there is a need to improve farmers' access to these technologies for large-scale adoption.

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Introduction

Healthy and fertile soils are the foundation for production of nutritious food. That's why, it is also said that soil anima also breeds human anima and vice-versa. While, soil formation is very slow process and it can take up to one millennium to form one centimeter of soil. As per FAO (2015) estimates about ninety-five percent of human food is produced in way or other on our soil. While, water and other medias used for plant growth share just five percent in the total food production. Therefore, sufficient and sustainable production of human and animal food demand to keep our soils healthy and fertile. Moreover, it has also been estimated that food production can be augmented up to fifty-eight percent through better soil management. Several biofertilizers developed in Pakistan by various research and academic institutions viz. BioPower by National Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad in year 1995; BioAbb by University of Agriculture Faisalabad (UAF) in year 2002, Biozote by Pakistan Agricultural Research Council (PARC), Islamabad in 2016 that was commercialized in year 2019, have the potential to improve farm production significantly, if properly demonstrated and disseminated (Dilshad *et al*., 2010; Hussain *et al*., 2002; Ullah *et al*., 2016).

Many of these are giving promising results at research stations. However, adoption at farm field level has not been determined due to their limited usage, mainly because of poor dissemination and limited demonstrations. Fortunately, main institutes mandated with land resources research viz. Soil Fertility and Research Institute (SFRI), Lahore; Soil and Water Conservation Research Institute (SAWCRI), Chakwal; Land Resources Research Institute (LRRI), PARC-National Agricultural Research Centre, Islamabad, and Institute of Soil and Environmental Sciences (IS & ES) University of Agriculture, Faisalabad have promoted their adoption at number of farms in the country in recent years (ICARDA, 2014). The Agriculture Extension Department in the country is promoting modern agricultural technologies through field demonstration, farmers gatherings, print and electronic media etc. While, well-established private sector supplies agriculture inputs to farmers. Nevertheless, delivery of technical training and follow-up services are limited. In this reference, print and electronic media can be utilized in dissemination of useful recommended information to farmers. However, none of these are fully used, severely underutilizing Pakistan's agricultural potential, where farm sector is particularly confronted with the challenge in declining soil fertility. Based on these realities, U.S. Department of Agriculture (USDA) sponsored a research and development project in the country 'Improving Soil fertility and Soil Health in Pakistan through Demonstration and Dissemination of Best Practices for Farmers. Under the project, USDA experts provided technical advice in soils and agriculture. They furnished programmatic support to involve relevant public and private sector agencies in joint activities. The overall aim of the project was to successfully demonstrate and disseminate techniques and technologies in soil management, to develop supporting analytical tools and provide extension materials/supplies to help farmers improve soil health and soil fertility in the country. The project was executed by the International Center for Agricultural Research in the Dry Areas ICARDA-Pakistan office through various institutions of Pakistan Agricultural Research Council viz. Land Resources Research Institute-LRRI, National Agricultural Research Centre (NARC), Agricultural Engineering Institute -AEI, NARC and Social Sciences Research Institute-SSRI, NARC; Soil Fertility Research Institute (SFRI), Lahore; University of Agriculture, Faisalabad (UAF); Sindh Agriculture Extension Services, Hyderabad; Soil and Water Conservation Research Institute (SAWCRI), Chakwal; National Centre of Excellence in Geology (NCEG), University of Peshawar and Agricultural Research Institute (ARI), Quetta. The project was executed in two phases, in the first phase (2013-2016) knowledge regarding these technologies had been disseminated among farmers, demonstrated sites were established, farmers were given hand-on trainings, and along with this a cadre of agricultural service providers (ASPs) was developed. In the second phase (2017-18) of the project adoption of promising technologies was enhanced by the technical partner institutes. ASPs facilitated technical institutes in the delivery of services and thus promoted adoption of these technologies on sustainable lines (Khan *et al*., 2021).

Soil health is defined as the persistent capacity of soil to function as vital living ecosystem that sustains biological productivity, maintain environmental quality, and promote plant and animal health (Doran and Parkin, 1994). While, soil fertility is its ability to provide nutrients required by plants in passable quantities and balanced proportions for plant growth and reproduction. Ideally a fertile soil does not contain toxic substances which may hinder plant growth (FAO, 2017). Extent of interactions between three main components of the soil viz. physical, chemical and biological, and inherent features of the soil determine level of soil fertility (Abbott and Murphy, 2003). Main characteristics that support soil fertility like its pH level and susceptibility to compaction are dependent on the constituents of the original parent rock. While, subsequent events, including the growth of plants and application of micronutrients, Biozote, fertilizers and other chemicals, modify the soil characteristics and improve its fertility. While, continuous use of synthetic fertilizers and other chemicals disrupt the delicate balance between the components of soil fertility (Yang *et al*., 2014).

Extensive pressure on land resources for production of food, fiber and other products has resulted in its extensive degradation. Thus, led to rapid depletion of natural resources for agricultural production. For example, in Africa alone 6.3 million acres of degraded agricultural land have lost its fertility and moisture holding capacity and will need to be regenerated to meet the demand for food needs of a population that will more than double over the next 40 years (FAO, 2017a). Extensive use of synthetic fertilizers has resulted in stagnant productivity of crops and causing environmental issues. Thus, integrated nutrient management approach is needed for sustainable agriculture (Wu and Ma, 2015). It is said that the application of '4Rs' i.e., right type of fertilizer in the right quantity at the right time in right place can improve soil health and fertility (Gaskell and Hartz, 2011). Similarly, appropriate organic matter contents and availability of micronutrients are essential for maintaining soil health (Bot and Benites, 2005). Therefore, adding micronutrients to crops, using biofertilizers to boost the effectiveness of conventional fertilizers, and planting seeds directly through crop residue management without tillage all improve soil health, which in turn increase both the situation regarding food security and farmers financial returns.

Agricultural Engineering Institute (AEI), PARC-National Agricultural Research Centre (NARC) designed the Pak Seeder to manage the rice residues after its mechanical harvest and to plant wheat by zero-till method in the same field. The Pak Seeder in a single operation cuts the loose rice residue, mulches it on the soil surface and plants wheat. The use of Pak Seeder saves 7-10 days at crop sowing stage, and considerably reduces cost of wheat production. Furthermore, there is no need to burn rice residues which would reduce the environmental pollution caused by the smoke. The burning not only creates environmental problems but also results in loss of carbon and crop nutrients, especially Nitrogen. The mulched residues decompose and enrich the soil with carbon and other minerals, enhancing its fertility and health. Land Resources Research Institute (LRRI), PARC-NARC promoted the use Biozote to increase wheat yield. Similarly, Soil Fertility Research Institute (SFRI), Lahore promoted the use of micronutrients for citrus orchards and vegetable grown under tunnels.

Adoption of technologies disseminated and demonstrated through the project could result in saving of resources and energy being consumed in production of chemical fertilizers, which are gradually getting scarce and expensive due to limited reserves (particularly rock phosphate). It is believed that use of alternatives, such as biofertilizers not only help in decreasing the use of synthetic fertilizers but also increases crops' yield, safeguards environment, improve soil health and quality of the produce. Biofertilizer developed by LRRI, commercially named as Biozote contains beneficial micro-organisms that help in achieving higher crop productivity. These microbes fix atmospheric nitrogen (N) and supply it to the host plants, solubilize the fixed phosphorus (P), and thus make it available for the plants, secrete hormone to stimulate plant growth, and protect plants from root-borne diseases. Social Sciences Research Institute (SSRI), PARC-NARC being a partner institute of the project served to provide link between collaborating partners and farmers to provide feedback about technologies demonstrated under the project. This research study has been planned to determine economic viabilities of the technologies demonstrated under the project viz. micronutrients (for citrus and off-season vegetables) and Biozote for wheat production.

Materials and Methods

The study is based on the data of input use and crop production at selected sites, where technologies were demonstrated through the Soil Fertility and Soil Health (SF & SH) project. Use of micro nutrients for citrus crop was demonstrated by Soil Fertility Research Institute (SFRI), Government of Punjab, Lahore in year 2015-16 at four sites in Sargodha district and at two sites in Toba Tek Singh district. SFRI demonstrated the use of technology at 13 sites for off-season vegetables production under plastic tunnels in year 2014-15 and 2015-16; including five sites for chili peppers; two in Sheikhupura and three

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in Gujranwala; three sites for cucumbers; one each in Sheikhupura, Gujranwala and Sahiwal, two sites for bell peppers in Okara, and two sites for bottle gourd production in Gujranwala. In citrus orchards, micronutrients were applied before flowering in the months of February-March to the soil at the rate 100, 75 and 25 grams per plant of Zinc (Zn), Iron (Fe) and Boron (B), respectively. In vegetables, Zn, Copper (Cu), Fe and B micro nutrients were applied to the soil at the rate of 12.5, 3.75, 2.5 and 2.5 kg per hectare, respectively. Biozote application for wheat crop was demonstrated by Land Resources Research Institute (LRRI), PARC-NARC at various sites in Punjab province. Out of these, data of eight irrigated sites (4 each in Chakwal district/ rain-fed zone and rice-wheat cropping zone of Punjab) in year 2015-16 have been used for the study. Economic viabilities of these technologies have been determined through marginal analysis i.e. additional benefits of adoption of each technology are compared with additional costs incurred by the adopters of each technology. Expression 1 below is generalized formula for marginal analysis.

$$Change\ in\ Net\ Benefits = Marginal\ Benefits - Marginal\ Costs \quad ...(1)$$

Results and Discussion

Micronutrients application for citrus orchards

In Kinnow mandarin, there was an thirteen percent increase in the productivity by applying micronutrients. Micronutrient application resulted in better fruit setting i.e., average number of fruits per plant increased from 550 to 619 (Table 1). This implies an increase of about 13 percent in fruit production with the use of the technology. Mean fruit production per plant with normal practice and with micronutrients application were 80 kg and 92 kg, respectively. Accordingly, the use of micronutrients resulted in 15 percent higher produce by weight. Increase in gross revenue due to additional fruit production was Rs.55723 per hectare. Use of micronutrients also resulted in production of quality produce and farmers fetched 10 percent higher prices for their produce. Improvement in the quality and resultant premium price of the produce at farms using micro nutrients can be attributed to large fruit size, less incidence of citrus canker disease, better fruit colour, improved appearance and uniformity in the size of the produce. These results are consistent with that of Ilyas *et al.* (2015), they reported that micronutrients viz. Zn, Cu and B are essential for optimal physiological and biochemical pathways of plant growth in citrus cultivation under agroclimatic conditions of Punjab, Pakistan. Similarly, Ashraf *et al.* (2012, 2013, 2014) and Razaaq *et al.* (2013) reported that Zinc application improve citrus productivity and juice quality. In the same way, Tariq *et al.* (2007) and Ashraf *et al.* (2012) reported that foliar application of micronutrients increased the number of fruits per tree and juice volume per Kinnow fruit. Similarly, application of boron enhances the fruit set (Perica *et al.*, 2001), and that of copper boost the fruit yield per acre (Khurshid *et al.*, 2008).

Application of micronutrients to citrus increases plant vigor and hence boost immunity against various diseases including citrus canker. Imran *et al.* (2015) stated that citrus canker adversely affects plant health and fruit development and causes huge economic loss worldwide. Thus, they stressed on screening of nursery plants against the disease as a preventive measure. While, use of micronutrients can be considered as a loss minimizing strategy. Similarly, Sharif *et al.* (2021) reported that citrus canker incidence increases with rise in temperature, relative humidity and wind speed. They stated that use of chemicals is the cheapest and easiest way to control the disease; however, environment considerations like pollution and its impact on the ecosystem should never be overlooked. Findings of current study reveal that use of micronutrients resulted in an increase in gross revenue by Rs.61296 per hectare. While, average cost of micronutrients application on one-hectare orchard was Rs.9139. Thus, use of the technology resulted in an increase in net revenue by Rs.52157 per hectare. In this way, use of micronutrients resulted into a benefit cost-ratio of 5.71, i.e., one Rupee invested for the application of micronutrients generated additional benefit of Rupee 5.71. The results are consistent with Singh *et al.* (2019), they emphasized the role of micronutrients in profitable production of Kinnow mandarin. They stated that application of micronutrients is vital in ensuring maximum returns to the farmers as Kinnow is a prolific bearer and offers maximum return among citrus crops. Use of micronutrients enhance the overall acceptability of the fruit by improving the quality characteristics including juice content. They emphasized that though acute micronutrient deficiency may not be apparent, yet plants have a hidden demand for micronutrients that, if fulfilled, allows for high-quality output.

Table 1: *Effect of micronutrient (MN) application on productivity citrus orchards (2015-16).*

Treatment	Mean	Std. Dev.	Minimum	Maximum
Farmer practice (Number of fruits per plant)	550	238	350	874
MN application (Number of fruits per plant)	619	220	426	917
Additional fruit obtained with MN application (Number per plant)	71	36	38	128
Increase in gross revenue due to additional fruit @ Rs. 3.5 per fruit	248	126	133	448
Increase in gross revenue (Rs. per hectare) (On an average 556 fruit trees per hectare)	55,723	28,365	29,894	1,00,697
Increase in gross revenue per hectare due to quality fruit production (10% increase in price)	5,572	2,837	2,989	10,070
Total increase in gross revenue (additional fruit + quality) (Rs. per hectare)	61,298	31,202	32,884	1,10,767
Cost of MN application (Rs. per hectare)	9,139	-	-	-
Net revenue per acre with micro nutrient application	52,159	22,063	23,745	1,01,628

Note: Results are based on production record of six farms applying micro-nutrients.

Table 2: *Effect of micronutrient (MN) application on productivity of chilies produced in tunnels (2014-16).*

Treatment	Mean	Std. Dev.	Minimum	Maximum
Farmer Practice (ton per hectare)	45.22	14.46	27.33	63.26
With MN Application (ton per hectare)	59.60	8.87	50.92	70.34
Increase in productivity (ton per hectare)	14.38	7.68	6.19	23.60
Price (Rs. per ton)	23,546	475	22,800	23,960
Increase in gross revenue (Rs. per hectare)	339915	185290	145574	565408
Increase in gross revenue due to better quality produce @ 5% (Rs. per hectare)	70,046	9,428	61,006	82,647
Total increase in gross revenue (Rs. per hectare)	4,09,962	1,80,326	2,09,976	6,26,414
Cost of MN application (Rs. per hectare)	14,079	676	13,585	14,820
Net increase in gross revenue (Rs. per hectare)	3,95,883	1,79,731	1,96,391	6,11,594

Note: Results are based on production record of five farms applying micro-nutrients, 3 farms in 2014-15 and 2 farms in 2015-16.

Micronutrients application for off-season vegetables production

Vegetables are rich source of many nutrients, including potassium, dietary fiber, folate, and vitamins A & C (USDA, 2022). The consumption of chili peppers for alleviating human micronutrient dietary deficiencies has been stressed in literature. Olatunji and Afolayan (2018) emphasized that chili peppers contain a wide range of vitamins, minerals, phytochemicals, and dietary fiber. Findings of this study revealed that off-season chili pepper production with and without use of micronutrients was 45.22 and 59.60 ton per hectare, respectively (Table 2). Thus, increase in productivity was 31.9 percent. The results are consistent with Baloch *et al.* (2008), they studied the effect of foliar application of macro and micro nutrients on production of green chilies and reported 6.3 to 42.3 percent increase in the yield by using 4ml/L to 8ml/L concentration. In the same way, Askari *et al.* (1995) reported that foliar application of micronutrients resulted in earlier flowering and fruiting (up-to twenty days) in Chili Peppers as compared to the control. The treated plants bore more fruits and their size was also bigger than those of the control group. Results of present study revealed that cost of micronutrients application per hectare for chilies production was Rs. 14079. Which resulted into an increase in gross revenue per hectare of Rs.409962 (83% through increase in production and 17% through better price of quality produce). Increase in net revenue was Rs.395883 per hectare, with benefit-cost ratio of 28.1. Cucumbers have many health benefits, as these are low in calories, carbohydrates, sodium, fat and cholesterol (USDA, 2022). Use of micronutrients resulted in a considerable increase in yield of cucumber in off-season farming under tunnels as compared to usual practice of farmers in off-season cumber production. Cucumber's productivity increased by 40.6 percent from 60.37 to 84.88 ton per hectare with micronutrients application in 2014-16 (Table 3). Similarly, Yadav *et al.* (2020) reported significant improvement in growth parameters and yield attributes. They reported the fruit yield ranged from 18.0 to 76.1 ton per hectare based on experiments to determine effect of micronutrients on the productivity under polyhouse conditions. Likewise, Mansourabad *et al.* (2016) reported increase in cucumber yield due to use of micronutrients (iron, zinc and silicon). Cost of micronutrients application per hectare was Rs.13585 (Table 3). Which resulted into an increase in gross revenue of Rs.249997 per hectare (85% through increase in production and 15% through better price of quality produce). Increase in net revenue per hectare with micronutrients application to cucumber crop produced under tunnels was Rs.236412, with benefit-cost ratio of 17.4 i.e., one Rupee investment in application of micronutrients for cucumber production gives additional returns of Rupee 17.4.

Bottle gourds are enriched with essential edible products and fibers (Palamthodi *et al.*, 2019). Application of micro-nutrient for bottle gourd production have significant impact on growth and reproductivity (Abbas *et al.*, 2020). As per findings of current study, production of bottle gourd produced in tunnels with and without use of micronutrients was 24.43 and 31.70 ton per hectare, respectively (Table 4). Thus, increase in productivity through micronutrients application was 29.9 percent. Cost of micronutrients application per hectare was Rs.12844. Which resulted into an increase in gross revenue per hectare of Rs.192307 (93% through increase in production and 7% through better price of quality produce), with benefit-cost ratio of 15.0. Production of bell papers produced in tunnels with and without use of micronutrients was 46.17 and 41.53 ton per hectare, respectively (Table 5). Thus, increase in productivity was 11.1 percent. Cost of micronutrients application per hectare was Rs. 13091. Which resulted into an increase in gross revenue per hectare of Rs.161854 (67% through increase in production and 33% through better price of quality produce). Increase in net revenue was Rs.148763 per hectare, with benefit-cost ratio of 11.4. i.e., one Rupee investment in application of micronutrients for bottle gourd production gives additional returns of Rupee 11.4.

Table 3: *Effect of micronutrient (MN) application on productivity of cucumbers produced in tunnels (2014-15).*

Treatment	Mean	Std. Dev.	Minimum	Maximum
Farmer Practice (ton per hectare)	60.37	13.77	45.78	73.15
With MN Application (ton per hectare)	84.88	31.25	50.71	111.99
Increase in productivity (ton per hectare)	24.51	17.56	4.93	38.84
Price (Rs. per ton)	8,466	978	7,640	9,546
Increase in gross revenue (Rs. per hectare)	2,13,586	1,53,365	37,628	3,18,885
Increase in gross revenue due to better quality produce @ 5% (Rs. per hectare)	36,411	14,795	19,370	45,971
Total increase in gross revenue (Rs. per hectare)	2,49,997	1,68,147	56,998	3,64,856
Cost of MN application (Rs. per hectare)	13,585	-	-	-
Net increase in gross revenue (Rs. per hectare)	2,36,412	1,68,147	43,413	3,51,271

Note: Results are based on production record of three farms applying micro-nutrients.

Table 4: *Effect of micronutrient (MN) application on productivity of bottle gourds produced in tunnels (2015-16).*

Treatment	Mean	Std. Dev.	Minimum	Maximum
Farmer Practice (ton per hectare)	24.43	10.78	16.81	32.05
With MN Application (ton per hectare)	31.7	12.59	22.82	40.63
Increase in productivity (ton per hectare)	7.30	1.82	6.01	8.58
Price (Rs. per ton)	23,100	-	-	-
Increase in gross revenue (Rs. per hectare)	1,68,515	41,979	1,38,831	1,98,198
Increase in gross revenue due to better quality produce @ 5% (Rs. per hectare)	36,637	14,546	26,351	46,922
Total increase in gross revenue (Rs. per hectare)	2,05,151	56,524	1,65,182	2,45,120
Cost of MN application (Rs. per hectare)	12,844	-	-	-
Net increase in gross revenue (Rs. per hectare)	1,92,307	56,524	1,52,338	2,32,276

Note: Results are based on production record of two farms applying micro-nutrients

Table 5: *Effect of micronutrient (MN) application on productivity of bell peppers produced in tunnels.*

Treatment	Mean	Std. Dev.	Minimum	Maximum
Farmer Practice (ton per hectare)	41.53	25.83	23.36	71.10
With MN Application (ton per hectare)	46.17	28.48	25.96	78.74
Increase in productivity (ton per hectare)	4.63	2.66	2.60	7.64
Price (Rs. per ton)	23,315	27	23,300	23,346
Increase in gross revenue (Rs. per hectare)	1,08,044	61,850	60,487	1,77,965
Increase in gross revenue due to better quality produce @ 5% (Rs. per hectare)	53,810	33,161	30,241	91,730
Total increase in gross revenue (Rs. per hectare)	1,61,854	94,965	90,728	2,69,695
Cost of MN application (Rs. per hectare)	13,091	428	12,844	13,585
Net increase in gross revenue (Rs. per hectare)	1,48,763	95,109	77,884	2,56,851

Note: Results are based on production record of three farms applying micro-nutrients, two farms in 2014-15 and one farm in 2015-16.

Table 6: *Effect of biozote application on productivity of wheat (2015-16).*

Treatment	Mean	Std. Dev.	Minimum	Maximum
Productivity with Farmer Practice (ton per hectare)	4.61	0.48	3.60	5.10
Productivity with Biozte Application (ton per hectare)	5.11	0.57	4.10	6.00
Increase in productivity (ton hectare)	0.50	0.19	0.30	0.90
Price (Rs. per ton)	28750	-	-	-
Increase in gross revenue (Rs. per hectare)	14375	5541	8625	25875
Cost of Biozote application (Rs. per hectare)	1556	-	-	-
Net increase in gross revenue (Rs. per hectare)	12819	5541	7069	24319

Biozote use for wheat and rice crops

Biozote technology was demonstrated under irrigated conditions in Chakwal district and rice-wheat zone of Punjab. Biozote is the inoculum of phosphorus solubilizing bacteria. The application of phosphorus solubilizing bacteria as biofertilizer helps in the availability of phosphorus in soil. Wheat production with and without application of Biozote in Punjab province was 4.61 and 5.11 ton per hectare respectively, thus increase in production was 0.5 ton per hectare (Table 6). Similarly, Khan *et al.* (2017) reported improvement in wheat productivity to some extent through application of Biozote at the adopters farms in rice-wheat zone of Punjab. According to findings of present study, cost of Biozote application per hectare was Rs.1556 which resulted into increase in gross revenue of Rs.14375. Thus, increase in wheat productivity was 10.8 percent, with a benefit cost ratio of 8.2. i.e., one Rupee invested in Biozote application generated Rupee 8.2. Moreover, increase in net revenue per hectare was higher in rice-wheat zone as compared to Chakwal district. In the same way, Muhammad *et al.* (2022) reported that application of Biozte under zero tillage in rice-wheat in Usta Muhammad area of Balochistan in year 2019 improved wheat crop yield by 36.94 percent over traditional wheat planting.

Use of Pak seeder for wheat sowing

Unfortunately, due to some institutional and technical limitations Pak-seeder technology could not be demonstrated effectively. The reasons include both technical issues in its manufacturing as well as farmer's constraints in its adoption. Pak-seeder is modified version of zero tillage drill with an added advantage to break down rice stubble and mulch it into the ground and drill wheat seed in the soil. Initial versions of the Pak-seeder were quite heavy and could not be operated with small tractors (46 HP or below). Later, AEI experts involved in its development in cooperation with private manufacturers used light weight plastic gears, but it could not get desired success due to frequent breakage of the gears. Furthermore, machine operators were not skillful to the standard level. Thus, desired results to sow wheat crop on time after rice could not be achieved. While, latest version of the machine is quite successful. It consists of a chopper that crushes the rice stubble and mulches it into the soil, and a sowing machine called Happy Seeder that sows the wheat through the mulch. Large-scale deployment of Happy Seeder helps control the burning of rice stubble, eliminating air pollution and loss of nutrients and organic carbon from burning, while maintaining or increasing wheat productivity (Sidhu *et al*., 2007). Benefits for farmers using Happy Seeders for wheat sowing include reduced fuel consumption and costs to grow crops, ability to sow at recommended times, and reduced irrigation costs (Sidhu *et al*., 2015). Along with these, Keil *et al*. (2021) reported significant savings in wheat production costs, amounting to USD 113 per hectare (Rs.32143 at prevailing exchange rate of Rs.284.45 per USD. They proposed political support for its widespread deployment on the basis of its social benefits of reducing air pollution and improving agriculture production in a sustainable way.

Conclusions and Recommendations

Usages of micronutrients for citrus orchards and vegetable produced in tunnels are lucrative. Similarly, Biozote application for wheat crop also has considerable marginal returns for the farmers. There is a need for wider dissemination and demonstration of these economically viable technologies for their rapid adoption. Estimation of the business volume of micronutrients is necessary to systematize the availability. This would increase farmers' access and adoption of these productivity enhancing inputs. Biozote is a delicate product, there is need to develop its cold chain transportation and distribution mechanisms. Furthermore, biological scientists should take samples during distribution and marketing phases to confirm viability of microorganism. Improved management system of its distribution and marketing will result in increased efficiency and higher productivity of wheat and other field crops.

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Novelty Statement

Several soil fertility and soil health improving technologies have been developed in Pakistan. Adoption of these technologies could result in savings of valuable resources and energy at farm level. However, adoption of these technologies isn't quite encouraging. In this article, economic viabilities of selected technologies viz. micronutrients application for citrus fruits and for off-season vegetables, use of Biozote for wheat crop, and Pak Seeder technology for sowing wheat crop by zero-till method are determined through marginal analysis. Findings are useful for researchers to adapt these technologies according to farmers' needs, extension agents to convince farmers to adopt promising technologies at large scale, and farmers to compare cost and benefits of these technologies with alternate options available for use at farm level.

Author's Contribution

Abid Hussain: Overall management of the article, including data collection, editing, entry and its analysis, review of relevant literature and write up. Incorporated technical comments of the reviewers in consultation with coauthors.
Hassnain Shah: Conceived the idea, supervised data collection process and provided technical input at every step.
Muhammad Nadeem Iqbal: Provided list of adopters/ provided data and technical inputs about use of micro-nutrients for vegetables production in tunnels.
Tariq Sultan: Furnished list of adopters of biozote technology for wheat production and provided technical input about the use of the technology and description of the result.

Conflict of interest
The authors have declared no conflict of interest.

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