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Economic Analysis of Durum Wheat Production Under Nitrogen and Sulfur Fertilization in Southeast Ethiopia

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Abstract

Durum wheat is a preferred raw product for pasta making due to its gluten strength. Nitrogen and Sulfur are nutrients required both for yield and quality. A replicated field trial was conducted at two locations in 2011 in southeast Ethiopia to evaluate profitability of nitrogen and Sulfur fertilization in durum wheat. Net benefit, marginal rate of return, residual and value-cost ratio were the economic parameters used for evaluation. The treatments included nitrogen levels of 0, 60, 120 and 180 kg N/ha and Sulfur levels of 0, 15, 30, 45 and 60 kg S/ha. Economic analysis was done based on partial budget according to CIMMYT procedure. The economic analysis considered two scenarios: premium price for quality product and normal market price. The result showed significant difference between sites and fertilizer rates in response to grain yield. For no premium price production, 60-0 kg N-S/ha was proved profitable for the research station with MRR of 108% whereas 60-15 kg N-S/ha was chosen for the farm site with MRR of 624%. However for premium price scenario, 60-45 kg N-S/ha was selected at the station with MRR of 248% whereas 180-60 kg N-S/ha is the chosen level for the farm site with MRR of 120%. In conclusion, application of 180-60 kg N-S/ha fertilizer for on-farm durum wheat production with premium price is a profitable technology for quality durum wheat production in the highlands of South-eastern Ethiopia..

Introduction

Durum wheat is the second most cultivated wheat species in the world next to bread wheat [1]. It is the hardest of all wheats; its density combined with high protein content and gluten strength makes it the preferred choice for producing premium pasta products. Pasta made from durum wheat is firm with consistent cooking quality. Semolina of durum wheat is the preferred raw material for the production of high quality pasta, due to its unique colour, flavour, and cooking quality. Pasta is a popular wheat-based food worldwide, due to its convenience, cost, palatability and nutritional value [2]. Starch and proteins are the major components of durum wheat semolina [3]. Albumins and globulins, which are soluble proteins in water and saline solutions respectively [1,4], are minor fractions (20%) which contain high levels of lysine as compared to the gluten proteins (gliadins and glutenins, 80%). Soluble proteins have metabolic functions in wheat kernels. In addition, they are important when considering resistance of the grain to stored insects pests [5]. Gluten proteins, called prolamins, contain storage proteins which contain subunits called gliadins and glutenins. Productivity is limited, among other factors, by low soil fertility because of which fertilizers are becoming important inputs for maximize crop yield and end-use quality. Nitrogen is a macronutrient required by plants in comparatively larger amounts than other elements. Soil nitrogen depletion, poor crop productivity and the ensuing human misery are serious problems in East African highlands [6].

Recent studies have shown significant yield responses of wheat to S fertilization, particularly in areas of low S deposition and with light-textured or shallow calcareous soils [7,8]. Deficiency of S has been recognized as a factor limiting crop production in many regions of the tropics and subtropics in Africa [9]. Agricultural practices such as intensive use of non-sulfur fertilizers, changes in the timing of fertilizer applications; declining soil organic matter levels; and the introduction of higher yielding cultivars that deplete the reserve of soil S contributed to the S deficiency [10-12]. Low soil nutrient status, nutrient depletion due to erosion, leaching, and crop removal are the main constraints of low crop yields in Ethiopia contributing to the low national yield [13].

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The highland soils of Ethiopia tend to exhibit low organic matter content and consequently low total N. The amount of N fertilizer used in the country has increased by 22% from 1996 to 2005 which has not been supported by other essential nutrients like sulfur causing most soils to be sub-optimal and deficient. Furthermore, attention has not been given to nutrients other than nitrogen and phosphorus [10]. Very few studies have been conducted in the country, especially in the highlands, to investigate influence of N and S fertilizers on economic profitability of durum wheat. Hence, this study aimed at determining economic optimum rates of nitrogen and sulfur for durum wheat production in the highlands of Bale.

Materials and Methods

The experiment was conducted at two sites, Sinana research station (7°7'N, 38° 10'E and 2400 meters above sea level) and nearby farmer's field in the highlands of Bale, Southeast Ethiopia in 2011. A popular durum wheat variety among farmres, Bakalcha, was used for the study. Phosphorus fertilizers in the form of triple super phosphate (TSP, 46% P2O5) and Diammonium Phosphate (DAP: 18-46 N-P2O5) were used to supply equal amounts of phosphate to all experimental plots and Urea (46% N) was used as a source of nitrogen. The treatments consisted of four levels of nitrogen (0, 60, 120, and 180 kg N ha^{-1}), and five levels of sulfur (0, 15, 30, 45, and 60 kg S ha^{-1}), in an experiment laid out as a randomized complete block design with a factorial arrangement of 20 treatment combinations in three replications. Wheat seeds were sown at the recommended rate of 150 kg/ha. Nitrogen and sulfur rates greater than 30 kg/ha were applied in three splits (1/4th at sowing, 1/2 at mid-tillering stage, and 1/4th at flowering).

Soil samples were taken and analyzed for organic carbon, total N, available S, Exchangeable K, soil pH, available phosphorus, cation exchange capacity (CEC) and textural analysis using standard laboratory procedures. Economic analysis was done based on partial budget for scenarios which compare premium and normal market price scenarios. CIMMYT procedure (CIMMYT 1998) for partial budget analysis was followed. Grain yield was adjusted down to 10% and then gross filed benefit was calculated based on market price of durum wheat at the farm gate. The costs incurred in the durum wheat production were cost of nitrogen and sulfur fertilizers and the application cost of these fertilizers. Net benefit was calculated by subtracting gross field benefit from total variable cost. Marginal cost and marginal benefit were calculated by successively subtracting the higher from the immediate lower levels of technologies. Marginal rate of return was calculated dividing marginal return by marginal cost and multiplying by 100. Residue was calculated by subtracting the total variable cost from net benefit whereas the value cost ratio was calculated dividing net benefit by the total variable cost.

Results and Discussion

Soils at the research station and farmers field have low total N of 0.18 and 0.17%, very low organic carbon of 1.96 and 1.84%, medium to very low available P content of 10.10 and 4.22 mg/kg, very high exchangeable potassium of 1.38 and 5.81 cmol/kg, very high to high CEC of 46.91 and 34.24 cmol/kg and medium to high available sulfur of 21.83 and 25.99 mg/kg, respectively (Table 1).

Grain Yield

There was significant difference across locations where the trial on farmer's field resulted in higher grain yield than on-station (Figure 1). The interaction effect of nitrogen and sulfur on grain yield was not significant and hence grain yield increased as both nitrogen and sulfur rates increased at both

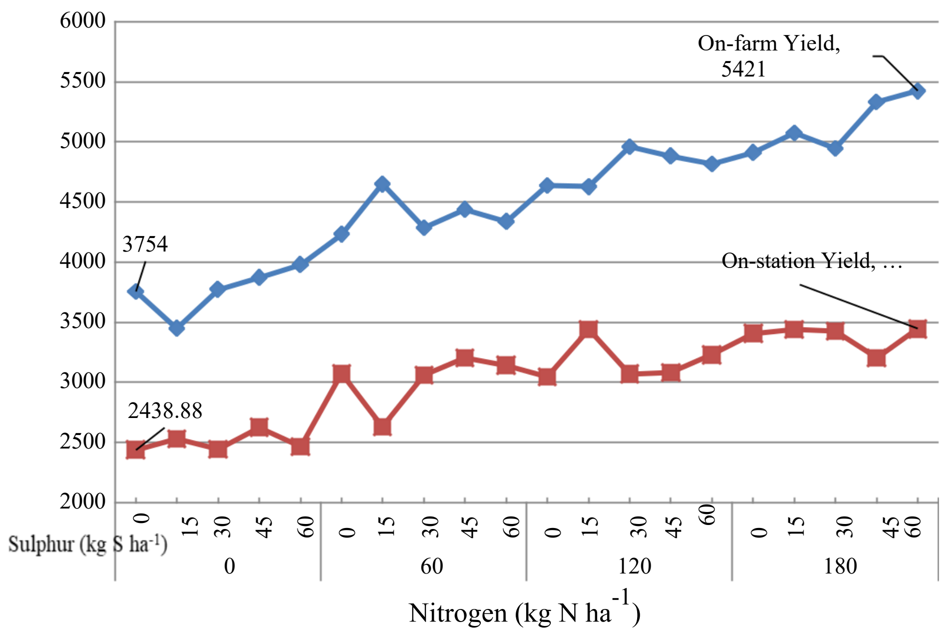

Figure 1: Grain yield response to nitrogen and sulfur fertilization.

Table 1: Physico-chemical properties of the test soils.

Parameter	Method			Unit	Value	
					station site	Farm site
pH	Potentiometric			01:02.5	6.67	6.29
Exchangeable K	Ammonium Acetate-Flame photometry			Cmol (+)/kg soil	1.38	5.81
CEC	Ammonium Acetate-Ammonia distillation			Cmol (+)/kg soil	46.91	34.24
Available S	Monocalcium	phosphate	extract	mg/kg	21.83	25.99
	Turbidimetry					
Available P	Olsen method			mg/kg	10.1	4.22
Organic C	Walkley and Black			%	1.96	1.84
Total N	Kjeldahl			%	0.18	0.17
Soil Texture	Hydrometer			%	Sand= 37	Sand=29
					Silt= 12	Silt=30
					Clay= 51	Clay=41
				Textural class	Clay	Clay

K= Potassium; CEC= Cation Exchange Capacity; S = Sulfur; P = Phosphorus; C = Organic Carbon; N= Total Nitrogen

sites. Grain yield of durum wheat on farmer's field was higher by 1.32 and 1.97 tons ha^{-1} at the rates of 0-0 and 180-60 kg N-S ha^{-1}, respectively than the yield obtained at the research station. Grain yield increased from 2.44 to 3.45 tons ha^{-1} for the research station as fertilizer rate increased from 0-0 to 180-60 kg ha^{-1} N-S whereas yield increased from 3.75 to 5.42 tons ha^{-1} as fertilizers increased in similar manner for the farmer's field. This shows a 41.4% yield increment for the research field and 44.5% increment for the farmer's field as N and S fertilizers increased from the control to the maximum rates.

Partial Budget Analysis

The economic analysis considered two different scenarios: the farmers sell their product at the farm gate price with no premium price and the second case where farmers are paid premium price for quality product. In the premium price case, 10 Ethiopian Birr (ETB) is paid for every 0.1% protein level increment starting from the base protein content of 10.5%. However in the no premium price, there is no extra price for additional protein content. Higher rate of nitrogen and sulfur will not always be correlated with economic benefit because there is no additional price paid for improved quality. Although the higher fertilizer rates have productd higher yield, the lower rates of nitrogen and sulfur were found to be more economical than the higher rates at both sites. Marginal analysis was performed and the decision for minimum rate of return, according to the CIMMYT procedure, is 50-100%. For the new technology to recommend for use by farmers, the minimum rate of return is 100% which farmers refers to as a 2 to 1 return in investment (Table 2, Table 3 and Table 4). Therefore, the decision for recommendation was based on marginal net of return beyond 100% where farmers need to feel secure for gaining return from the investment they would make on the new technology.

For all marginal rates of return above 100%, the minimum return with highest net benefit is selected, and then residue was calculated as the difference between net benefit and total variable cost to cross-check the chosen technology. The highest residue is selected and it corresponded to the appropriate marginal return to be selected. Tables 2 and 4 show a full combination of N and S treatments with their budget evaluation criteria and adjusted price values based on protein content for the station and farm sites, respectively. As we move from one level to the other treatment combination, the net benefit less than the previous level will be dominated (labelled D) and hence dropped out and only those increasing (un-dominated) were evaluated further (Tables 3 and Table 5). A profitable technology was selected for the no-incentive mechanism for additional quality product at the research based on the partial budget analysis and hence 60-0 kg/ha N-S fertilizer combination at the research station products 3072.57 kg/ha with net benefit of 14,871 ETB (Table 3). The marginal rate of return was found to be 108%, a return of additional 8 ETB for every 1 ETB invested. The highest residue and lowest value cost ratio also supported 60-0 kg/ha N-S fertiliser rate to be a feasible level. Result from the farm site should predict the farmers' condition well than the research station and hence our final recommendation focuses on economic return from the farm trial. The 60-15 kg/ha N-S rate productd 4649.75 kg/ha at on-farm site with net benefit of 23,076 ETB and marginal rate of return of 1942% (Table 5) indicating additional 942 ETB for every ETB invested using 60-15 kg/ha N-S fertilizer with the related costs. The highest residue and lowest value cost ratio also proves the selected rate profitable. Partial budget for the farm site in the incentivized case depicted a highest net benefit of 35,076 ETB with a net return on investment of 20 ETB if a farmer would use 180-60 kg/ha N-S fertilizer (Table 6).

The residue and the value cost ratio are also complementary indices for selecting this level to be economically feasible for on-farm production of durum wheat with the goal of obtaining 5421.5 kg/ha yield and a grain protein content of 13%. When we look at the budget analysis for the station site in the incentivized scenario, the last feasible rate 180-0N-S productd a marginal rate of return below 100% which is not feasible (Table 7). This has necessitated choosing the second feasible option, 60-45 kg/ha N-S, that products the highest return of 148 additional birr on investment supported with the highest residue. The critical factor to boost protein content appears to be nitrogen level under different sulfur

Table 2: Economic analysis of durum wheat as influenced by nitrogen and sulfur fertilization at sinana station.

N	S	GY	AGY	UnGFB	PC	AGFB	UC	GC	AC	TVC	UnNB	ANB
0	0	2438.88	2194.99	13,170	11.6	15,584	0	0	0	-	13,170	15,584
0	15	2530.68	2277.61	13,666	10.5	13,666	0	286.52	25	312	13,354	13,354 D
0	30	2444.73	2200.26	13,202	11.1	14,522	0	573.04	50	623	12,579 D	13,899
0	45	2626.97	2364.27	14,186	11.5	16,550	0	859.56	75	935	13,251	15,615
0	60	2465.36	2218.82	13,313	10.7	13,757	0	1146.08	90	1,236	12,077 D	12,521 D
60	0	3072.57	2765.31	16,592	12.4	21,846	1695.65	0	25	1,721	14,871	20,125
60	15	2632.56	2369.30	14,216	12.0	17,770	1695.65	286.52	50	2,032	12,184 D	15,738 D
60	30	3061.21	2755.09	16,531	12.8	22,867	1695.65	573.04	75	2,344	14,187	20,524
60	45	3201.66	2881.49	17,289	12.8	23,916	1695.65	859.56	90	2,645	14,644	21,271
60	60	3144.18	2829.76	16,979	12.3	22,072	1695.65	1146.08	115	2,957	14,022 D	19,115 D
120	0	3046.94	2742.25	16,453	12.0	20,704	3391.3	0	50	3,441	13,012 D	17,263 D
120	15	3442.02	3097.82	18,587	12.1	23,729	3391.3	286.52	75	3,753	14,834	19,976
120	30	3068.77	2761.89	16,571	12.6	22,371	3391.3	573.04	100	4,064	12,507 D	18,307 D
120	45	3083.36	2775.02	16,650	12.3	21,645	3391.3	859.56	125	4,376	12,274 D	17,269 D
120	60	3230.9	2907.81	17,447	13.2	25,298	3391.3	1146.08	150	4,687	12,759	20,611
180	0	3407.78	3067.00	18,402	13.8	28,523	5086.95	0	75	5,162	13,240	23,361
180	15	3441.71	3097.54	18,585	13.1	26,639	5086.95	286.52	90	5,463	13,122 D	21,175 D
180	30	3427.17	3084.45	18,507	13.2	26,835	5086.95	573.04	115	5,775	12,732 D	21,060 D
180	45	3202.53	2882.28	17,294	13.7	26,517	5086.95	859.56	140	6,087	11,207 D	20,430 D
180	60	3446.73	3102.06	18,612	13.9	29,159	5086.95	1146.08	165	6,398	12,214	22,761

N = Nitrogen (Kg ha^{-1}); S= Sulfur (Kg ha^{-1}); GY = Grain Yield (Kg ha^{-1}); AGY = Adjusted Grain Yield Down to 10%; UnGFB = Gross Field Benefit (Birr ha^{-1}) without premium price; PC = Protein Content (%); AGFB = Gross Field Benefit (Birr ha^{-1}) with premium price based on protein content; UC = Cost of Urea; GC = Cost of Gypsum (ETB); AC= Cost of Application (ETB); TVC= Total Variable Cost (Birr ha^{-1}); D = Dominated Technology

Table 3: Partial budget analysis of nitrogen and sulfur rates without premium price of durum wheat grain at Sinana station.

N	S	GY	AGY	GFB	UC	GC	AC	TVC	NB	MC	MR	MRR	Residue	VCR
0	0	2438.9	2194.9	13,170	0	0	0	0	13,170	-	-	-	13,170	-
0	15	2530.7	2277.6	13,666	0	286.5	25	312	13,354	312	184	59	13,042	42.8
60	0	3072.6	2765.3	16,592	1695	0	25	1,721	14,871	1409	1,517	108	13,150	8.6

VCR = Value Cost Ratio (NB/TVC); Residue = NB-TVC; Adjusted Yield = Adjusted Grain Yield to 10%; NB = Net Benefit; MC= Marginal Cost; MRR = Marginal Rate of Return

Table 4: Economic analysis of durum wheat as influenced by nitrogen and sulfur fertilization at sinana on- farm.

N	S	GY	AGY*	UnGFB	PC	AGFB	UC	GC	AC	TVC	UnNB	ANB
0	0	3753.84	3378	20,271	11.7	24,325	0	0	0	-	20,271	24,325
0	15	3449.91	3105	18,630	12.5	24,839	0	286.52	25	312	18,318D	24,528
0	30	3773.66	3396	20,378	13.1	29,208	0	573.04	50	623	19,755	28,585
0	45	3872.70	3485	20,913	12.5	27,883	0	859.56	75	935	19,978	26,949 D
0	60	3980.25	3582	21,493	12.4	28,300	0	1146.08	90	1,236	20,257	27,063
60	0	4232.38	3809	22,855	12.5	30,473	1695.65	0	25	1,721	21,134	28,752
60	15	4649.75	4185	25,109	12.1	31,804	1695.65	286.52	50	2,032	23,076	29,772
60	30	4286.58	3858	23,148	12.1	29,320	1695.65	573.04	75	2,344	20,804D	26,977 D
60	45	4437.30	3994	23,961	12.8	33,147	1695.65	859.56	90	2,645	21,316	30,501
60	60	4336.67	3903	23,418	13.3	34,346	1695.65	1146.08	115	2,957	20,461D	31,390
120	0	4636.31	4173	25,036	11.7	30,043	3391.30	0	50	3,441	21,595	26,602 D
120	15	4627.12	4164	24,986	11.9	30,817	3391.30	286.52	75	3,753	21,234D	27,064
120	30	4959.36	4463	26,781	12.2	34,368	3391.30	573.04	100	4,064	22,716	30,304
120	45	4883.23	4395	26,369	11.6	31,204	3391.30	859.56	125	4,376	21,994D	26,828 D
120	60	4816.09	4334	26,007	13.2	37,710	3391.30	1146.08	150	4,687	21,320D	33,023
180	0	4910.58	4420	26,517	12.4	34,914	5086.95	0	75	5,162	21,355	29,752 D
180	15	5072.28	4565	27,390	12.8	37,890	5086.95	286.52	90	5,463	21,927	32,426
180	30	4945.20	4451	26,704	11.4	30,710	5086.95	573.04	115	5,775	20,929D	24,935 D
180	45	5329.39	4796	28,779	12.2	36,933	5086.95	859.56	140	6,087	22,692	30,846
180	60	5421.50	4879	29,276	13.0	41,474	5086.95	1146.08	165	6,398	22,878	35,076

N = Nitrogen (Kg ha^{-1}); S = Sulfur (Kg ha^{-1}); GY= grain yield (Kg ha^{-1}); AGY = adjusted grain yield down to 10%; UnGFB = Gross Field Benefit (Birr ha^{-1}) without premium price; PC= Protein content (%); AGFB = Gross Field Benefit (Birr ha^{-1}) with premium price based on protein content; UC= cost of Urea; GC= Cost of Gypsum (ETB); AC= cost of application (ETB); TVC= Total Variable Cost (Birr ha^{-1}); D = dominated technology

Table 5: Partial budget analysis of nitrogen and Sulfur rates without premium price of durum wheat grain at the on-farm site

N	S	GY	AGY	UnGFB	UC	GC	AC	TVC	NB	MC	MR	MRR	Residue	VCR
0	0	3753.84	3378	20,271	0	0	0	0	20,271	-	-	-	20,271	-
60	0	4232.38	3809	22,855	1695.65	0	25	1,721	21,134	1721	863	50	21,109	12
60	15	4649.75	4185	25,109	1695.65	286.52	50	2,032	23,076	311	1,942	624	23,026	11

VCR = Value Cost Ratio (NB/TVC); Residue= NB-TVC; Adjusted Yield = adjusted grain yield to 10%; NB = Net Benefit; MC = marginal cost; MRR = marginal rate of return

Table 6: Partial budget analysis of nitrogen and sulfur rates based on adjusted return to premium price at on- farm site.

N	S	GY	AGY	PC	AGFB	UC	GC	AC	TVC	ANB	MC	MR	MRR	Residue	VCR
0	0	3753.84	3378	11.7	24,325	0	0	0	0	24,325	0	0	0	24,325	
0	15	3449.91	3105	12.5	24,839	0	286.52	25	312	24,528	312	203	65	24,216	78.6
0	30	3773.66	3396	13.1	29,208	0	573.04	50	623	28,585	311	4,057	1305	27,962	45.9
60	0	4232.38	3809	12.5	30,473	1695	0	25	1,721	28,752	1098	167	15	27,031	16.7
60	15	4649.75	4185	12.1	31,804	1695	286.52	50	2,032	29,772	311	1,020	328	27,740	14.7
60	45	4437.3	3994	12.8	33,147	1695	859.56	90	2,645	30,501	613	729	119	27,856	11.5
60	60	4336.67	3903	13.3	34,346	1695	1146.1	115	2,957	31,390	312	889	285	28,433	10.6
120	60	4816.09	4334	13.2	37,710	3391	1146.1	150	4,687	33,023	1730	1,633	94	28,336	7
180	60	5421.5	4879	13	41,474	5086	1146.1	165	6,398	35,076	1711	2,053	120	28,678	5.5

VCR = Value Cost Ratio (NB/TVC); Residue = NB-TVC; Adjusted Yield = Adjusted Grain Yield to 10%; NB = Net Benefit; MC = Marginal Cost; MRR = Marginal Rate of Return

Table 7: Partial budget analysis of nitrogen and Sulfur rates based on adjusted return to premium price of durum wheat grain at the station site.

N	S	GY	AGY	PC	AGFB	UC	GC	AC	TVC	ANB	MC	MR	MRR	Residue	VCR
0	0	2439	2195	12	15,584	0	0	0	0	15,584	-	-	-	15,584	-
0	45	2627	2364	12	16,550	0	860	75	935	15,615	935	31	3	14,680	16.7
60	0	3073	2765	12	21,846	1,696	0	25	1,721	20,125	786	4,510	574	18,404	11.7
60	30	3061	2755	13	22,868	1,696	573	75	2,344	20,524	623	399	64	18,180	8.8
60	45	3202	2881	13	23,916	1,696	860	90	2,645	21,271	301	747	248	18,626	8
180	0	3408	3067	14	28,523	5,087	0	75	5,162	23,361	2,517	2,090	83	18,199	4.5

VCR = Value Cost Ratio (NB/TVC); Residue = NB-TVC; Adjusted Yield= Adjusted Grain Yield to 10%; NB = Net Benefit; MC = Marginal Cost; MRR = Marginal Rate of Return

rates as there is no change in protein content of 12% at the control up to 60-30 kg/ha N-S where it increased to 13%. Protein further increased to 14% at 180-0 kg/ha N-S but this level productd a return less than 100% and hence not appropriate for selection.

Conclusion

The recent premier price initiative for quality product has encouraged farmers to product durum wheat with higher protein content and drew their attention to focus on appropriate fertilization measures. The base price is for durum wheat productd with protein level of 10.5% and for every 0.1% increment in protein level, 10 additional ETB would be paid. This has encouraged farmers to orient their production towards quality and boosted durum wheat production in the area. Nitrogen and Sulfur have significant effect on yield and quality. The research station site productd lower yield and economic return compared to the farm site that better predicts the farmers' production situation. The final conclusion was based on the principle that the chosen technology is the one with highest net benefit, the least marginal rate of return above 100%, the highest residual and the minimum value-cost ratio.

Therefore, the selected technology for profitable durum wheat production in no-premium price scenario would be the use of 60-15 kg/ha N-S fertilizer producing 4649.75 kg/ha grain producing additional return of 942 ETB for every Birr invested in durum wheat. However in case of premium price, the use of 180-60 kg/ha N-S fertilizer will be the suitable technology for the farmers would invest to fetch additional return of 20 ETB for 1 ETB invested. On the contrary the technology option with the highest net benefit for the station site is not with the highest residual and it is with marginal rate of return below 100% which would mean no return for investing in durum wheat and therefore application of 60-45 kg/ha N-S fertilizer products 3201.66 kg/ha grain yield with the highest net benefit, residue and lower value cost ratio. Therefore, application of 60-45 kg/ha N-S at for the research station profitable with 48 birr return per a birr investment.

Data Availability

Data based on which this research was conducted can be accessed by contacting the corresponding author through sending emails at the address provided on the title page.

Conflicts of Interest

The author declare that there is no conflict of interest regarding the publication of this paper.

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