Benefit-cost Analysis of Rust, *Uromyces vicia fabae* Resistant Lentil Varieties Development

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Abstract

Lentil rust, *Uromyces vicia fabae* is a major disease of lentil causing grain yield loss of 25% in Ethiopia. Ex post analysis of investment on rust resistance lentil variety development was carried out to assess quantifiable benefit and briefly discuss intangible benefits resulted from the use of rust resistant improved lentil varieties in Gimbichu district in central Ethiopia. At 5% compounding interest rate, the Net Present Value was 2.33 million in 1963 constant Birr indicating that the investment was profitable. Similarly, the Internal Rate of Return was 38% which suggests that if money was borrowed at 38%, the benefit obtained from research, development and use of rust resistant lentil varieties would repaid the principal and the interest accrued in the time span considered. The benefit-cost ratio was 56:1 suggesting that a Birr invested in research and development of rust resistant lentil varieties would generate 56 Birr (in 1963 constant Birr). Therefore, public money spent for research and development of rust resistant lentil varieties was economical. In this scenario the intangible benefit includes biological nitrogen fixation, palatable straw for livestock, reduced weed pressure on the succeeding cereal crop, greater yield of split lentil and reduced rust disease in nearby districts.

Keywords: Benefit, cost, lentil, lentil rust, *Uromyces vicia fabae*, resistance

Introduction

Lentil rust (*Uromyces vicia fabae*) attacks all aerial plant parts of lentil causing about 25% yield losses in Ethiopia (Geletu et al. 1996), but complete crop failure is common when there is epidemic development (Negussie 2004). One method of managing lentil rust is the use of fungicides but small holder lentil growers cannot afford due to cost, unavailability, and lack of know-how on pesticide uses and applications. Moreover, cultural practices such as delay planting reduces rust severity but late planted lentil yield less than early planted ones; the effect of sowing date on rust also varies from location to location (Negussie 2004).

In Ethiopia lentil improvement program began around 1972 and one of the objectives of the improvement program was collection, evaluation, and selection of landraces for high yield and wider adaptability (DZARC 1983). These landraces were concomitantly evaluated for their reactions to diseases like root rot (*Fusarium oxysporum f. sp. lentis*), rust, Aschochyta blight (*Aschochyta lentis*) and powdery mildews *(Erysiphe polygoni)* and the majority of them were susceptible to all diseases including rust (DZARC 1983; Negussie 2004). This necessitated the

introduction and evaluation of exotic lentil genotypes developed at the International Center for Agricultural Research in the Dry Area (ICARDA) (Negussie 2004). Ethiopian government finances such agricultural research projects. As a consequence the public might enquire to know if money invested in research and development of modern varieties in general had been returned or not. Several exotic lentil genotypes were high yielding and rust resistant and released for production. Senait Regassa et al. (2006) evaluated the impact of adopting improved lentil varieties in the entire Ethiopia and found substantial variability among districts in adopting improved lentil varieties. However, although the research, development and the adoption of rust resistant lentil varieties were successful to some extent, the research was not evaluated in terms of economic return. The objective of this study was to assess quantifiable benefits and briefly discuss intangible benefits resulted from the use of rust resistant improved lentil varieties in Gimbichu district of central Ethiopia.

Methodology

Costs

Concerted efforts on lentil selection and crossing for rust resistance began in 1988 (DZARC 1989). Therefore, the year 1988 was taken as the year on which cost of developing high yielding and rust resistant variety began to accrue. Operational costs, scientist year costs, variety extension and demonstration costs covered by the Government of Ethiopia (GoE) and additional project fund provided by ICARDA were included. Operational costs were obtained from Ethiopian Institute of Agricultural Research (EIAR) directories and amended after consulting breeders and pathologists. Scientist year cost was estimated based on salary scale of the Harmaya (the then Alemaya) University of Agriculture and EIAR. The time allocated for rust resistant research, was determined based on total number of breeding trials (crossing, segregating populations, elite lines and yield trials) per year and percent time share for rust resistant research was determined. Scientist year cost was calculated by multiplying annual salary by percent time share for rust resistance research. For the calculation, each one pathologist, breeder, and technical assistant was considered.

Benefit

The first rust resistant lentil variety Adaa (FLIP-86-41L) was released for production in 1995 (Geletu et al. 1996). However, rust resistant varieties gained acceptance by farmers after the release of Alemaya in 1998. Thus, year 1998 was taken as the year on which benefit from rust resistant lentil cultivar began to accrue. Benefit was estimated using the following equation: $B_t = A_t * Y * YS * P_t$ where B_t = benefit in year t, A_t= total area (ha) under rust resistant lentil in year t, Y = yield (kg/ha), YS= yield saved (%), and P_t = price (Birr/kg) in year t.

Area

The area under the rust resistant variety Alemaya between 1997/98 and 2004/05 was obtained from Senait et al. (2006). In the absence of recorded data on area planted to improved variety, expert estimates (opinions) with reasonable level of accuracy are used (Morris & Heisey 2003). Thus, to estimate the area in 2006, 2007, and 2008 breeders and extensionist were consulted. According to these experts variety Alemaya occupies 95% of the total lentil area in Gimbichu District. The area covered by lentil in Gimbichu district was 2032.29ha in 2001/02 season (CSA 2002) and 95% of this area was used in estimating benefit between 2006/07 and 2008/9 (this area is much less than the area reported by Senait et al. (2006) in 2005/06 season, which was more than 2400ha).

Yield

Under farmer and researcher managed condition variety Alemaya yields 1.8 to 2.4t/ha and 2.0 to 3.0t/ha, respectively (Senait et al. 2006). The benefit was estimated using the lowest farmers' yield (1.8t/ha). Alemaya exhibits developmental and phenological plasticity (Geletu & Yadeta 1998), therefore it

is reasonable to assume a constant yield of 1.8t/ha for the entire time considered in the analysis.

Yield saved

Depending upon season, location, variety and lentil management techniques, loss caused by the rust disease varies greatly. For initial comparison the average annual yield loss of 25% was used. As worst case scenario the lowest yield save (2%) calculated from the 1990/91 loss assessment trial (DZARC 1991) was included.

Price of lentil grain

Average annual price of un-decorcated lentil grain in East Shewa Zone for 1997/98, 1998/99, 2000/01, and 2001/02 was obtained from the respective year report of the Central Statistical Authority. Average annual price for the 2006/07, 2007/08 and 2008/09 was obtained from Department of Socio-economics, Debre Zeit Agricultural Research Center. For the remaining years price was estimated using moving average price of three successive years.

After estimating benefits and costs of developing rust resistant lentil varieties, Net Present Value (NPV), Internal Rate of Return (IRR), and Benefit-Cost ratio (BC) were used to evaluate the lentil improvement project. Net Present Value is the sum of compounded series of costs outlaid and benefits obtained from the use of rust resistant lentil cultivars during the time period considered for the analysis- 1988 to 2008. The standard formula of NPV was used.

$$NPV = \sum_{t=0}^{T} B_t (1+i)^{T-t} - \sum_{t=0}^{T} C_t (1+i)^{T-t},$$

where B_t and C_t are benefit and cost, respectively in year t, i= interest rate, T= project period, and t= year IRR is the compound rate that equates NPV to zero, and B/C was calculated as ratio of compounded benefit to compounded cost. The project period was 20 years.

Interest rate

The interest rate consists of a real risk free rate, risk premium and inflation rate (Barry et al. 1995). Real risk free rate and risk premium were not taken into account because the exotic lentil genotypes used in the breeding and selection program were known to have rust resistant gene before they were evaluated under Ethiopian condition (therefore the probability of a genotype to be resistant was greater than the probability of being susceptible to rust). However, the inflation rate was adjusted using consumer price index (CPI) obtained from National Bank of Ethiopia (NBE 2004). CPI for the year 2006 to 2008 was obtained using linear regression equation (R^2 = 88.42, $P < 0.001$; $\alpha = 2.195$, $\beta = 0.4$ both significant at $P < 0.0001$). For initial evaluation of the research program 5% interest rate was used, then other interest rates (Table 2) were included for sensitivity analysis.

Result and Discussion

Tangible benefit

Uncompounded cost and benefit of rust resistant lentil variety development is shown in Table 1. Total cost outlaid and benefit accrued within 20 years period was 20,150 and more than 2.1 million in 1963 constant Birr, respectively. The NPV was positive 2.33 million in 1963 constant Birr at 5% interest rate and depending upon the interest rate used it ranged from 1.07 to 2.64 million in 1963 constant Birr, which showed that investing in rust resistant variety development was profitable. The Internal Rate of Return (IRR) was 37.9%. Depending upon the type of insect pest or disease resistance analyzed an IRR of 13% (Smale et al. 1998), 22% (Gardner et al., 1983), 39% (Azzam et al. 1997), 41% (Marasas et al., 2003) were reported. This suggests that if money was borrowed at 38% interest rate, the benefit obtained from research, development and use of rust resistant lentil varieties would have repaid the principal and the interest accrued in the time span considered. The benefit-cost ratio was 56:1 at 5% interest rate and depending upon the

interest rate used it varied between 1:1 and 95:1. For different insect pest and diseases benefit-cost ratio of 22 to 135 (Ervin et al. 1983), 2.7 to 24 (Ervin et al. 1996), and 27 (Marasas et al. 2003) were reported. It means that at 5% interest rate, a Birr invested in research and development of rust resistant lentil varieties would generate 56 Birr (in 1963 constant Birr). One way of incorporating sensitivity analysis is using different percentage of yield saved. If the yield saved was only 2%, the NPV would range from 0.04 at 15% interest rate to 0.16 million in 1963 constant Birr at 1% interest rate (Table 2). The IRR would be 16.58%. The benefit cost ratio would vary between 1.22 and 7.62 indicating that even using conservative estimate of 2% yield save investing in lentil rust resistance would generate sufficient benefit at least to cover costs outlaid. So far there is no evidence of rust resistance breakdown in the country (Negussie 2004). However, in order to buffer the pressure of a single variety on rust pathogen population, the lentil improvement program has released additional high yielding and rust resistant lentil varieties, namely, Alem Tena (FLIP-96-49L) and Teshale (FLIP-96-46L) (Senait et al. 2006). According to Carlson and Main (1976) if pest resistant variety remained under production for extended period of time, the benefit returned will increase in proportion to the age of that variety.

Table 1. Cost and benefit (Birr) of high yielding and rust resistant lentil variety development

Year	Total cost nominal	Benefit nominal	CPI*	Total cost Real	Benefit Real	Cost 1%	Benefit 1%
1988	6559.2	0	3.529	1858.66	0	2267.92	0
1989	6559.2	0	3.597	1823.52	0	2203.01	0
1990	6759.2	0	3.859	1751.54	0	2095.10	0
1991	6759.2	0	4.007	1686.85	0	1997.74	0
1992	8518. 6	0	3.997	2131.24	0	2499.05	0
1993	8518. 6	0	4.731	1800.58	0	2090.42	0
1994	9018. 6	0	4.950	1821.93	0	2094.26	0
1995	9018. 6	0	4.482	2012.17	0	2290.04	0
1996	12601.6	0	4.579	2752.04	0	3101.07	0
1997	12601.6	0	5.018	2511.28	0	2801.76	0
1998	0	86.04	5.271	0	16.32	0	18.03
1999	0	0	6.380	0	0	0	0
2000	0	43560	7.719	0	5643.22	0	6110.80
2001	0	146880	8.490	0	17300.35	0	18548.32
2002	0	38880	8.589	0	4526.72	0	4805.21
2003	0	73803	9.736	0	7580.42	0	7967.10
2004	0	153660	9.826	0	15638.10	0	16273.07
2005	0	5291460	9.195	0	575471.45	0	592908.81
2006	0	4630725.19	9.800	0	472516.36	0	482013.94
2007	0	4370083.99	10.200	0	428422.18	0	432706.40
2008	0	7124192.60	10.601	0	672049.74	0	672049.73
Total	86914.24	21873330.82		20149.81	2199164.87	23440.36	2233401.42

*1963=100, source National Bank of Ethiopia (2004)

Table 2. Effect of interest rate and percentage of yield saved on NPV and B/C ratio

Interest rate (%)	2% yield save		25% yield save	
	Net Present Value (million)	Benefit- cost ratio	Net Present Value (million)	Benefit- cost ratio
1	0.16	7.62	2.21	95.28
5	0.15	4.53	2.33	55.71
10	0.10	1.97	2.48	28.90
15	0.04	1.22	2.59	15.24
16.58	0.00	1.00	-	-
20	-0.13	0.65	2.64	8.17
25			2.53	4.45
30			2.10	2.46
35			1.07	1.39
37.9			0	1.00
40			-1.09	0.79

Intangible benefits

Quantifiable benefits are derived as crop return or revenue to lentil producers, whereas intangible benefits are benefits that are not quantifiable in monetary term. In this scenario the intangible benefit includes biological nitrogen fixation, palatable straw for livestock, reduced weed pressure on the succeeding cereal crop, greater yield of split lentil and reduced rust disease in nearby districts. In the cereal-legume based cropping system of Gimbichu, lentil is grown in rotation with tef and wheat. It fixes up to 107.1kg of nitrogen per hectare (Geletu et al. 1996) and the succeeding tef or wheat crop benefit from it and farmers reduce the amount of nitrogen fertilizer they apply on the succeeding cereals. Moreover, because of the rotation effect on weed flora, crops planted after lentil had less weed problem than continuous cereal cropping, which in turn reduces frequency of hand weeding or applications of herbicides.

Lentil straw contains nitrogen (1.12g/kg), phosphorus (0.17g/kg), sodium (0.01g/kg), potassium (1.25g/kg), calcium (0.73g/kg), magnesium (0.14g/kg), manganese (36.1mg/kg), copper (11.7mg/kg), iron (768mg/kg) and zinc (24.3mg/kg) (DZARC 1989), indicating that lentil straw is valuable feed sources for livestock. However, according to Negussie (2004) and Negussie et al. (2007) rust infected lentil straw contains greater phosphorus, nitrogen and crude protein than rust free plants. Even if rust infected straw contains greater amount of phosphorus, nitrogen and crude protein, rust infected straw is not preferred by animals for consumption. Rust resistant improved lentil varieties yield greater than the local (farmers') varieties ensuing to increased lentil supply to small scale lentil decorcating enterprise. Moreover, improved varieties especially Alemaya does not break at the time of splitting and the recovery rate is more than 80% (personal comm. Dr Million Eshete). It is also preferred in the local market due to its red cotyledons (Geletu & Yadeta 1998). Such situation might decrease consumer price eventually. In conclusion this *ex post* analysis revealed that public money invested in research and development of rust resistant lentil varieties was successful, even without considering the aforementioned intangible benefits.

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