

Review on impacts of bio-fertilizers on production practices and legume production in Ethiopia

Megersa Mengesha*

Hawassa University College of agriculture , School of plant and horticultural science, Ethiopia

ABSTRACT

Even though there is progress in production and productivity of agricultural produces, food insecurity and per capita calorie consumption in the world has not registered a significant improvement. Thus, adoption and diffusion of nutritious crops may be regarded as a good option for rural smallholder farmers. This paper reviews various articles and documents on production practice and impact of bio-fertilizer on legume production in Ethiopia. The production practice and impact of bio-fertilizer in legume production is of great significance in particular to developing countries due to their large dependence on agricultural practice for livelihoods and their lack of infrastructure for adaptation when compared to developed countries. Impact and production practice affected by Training, Extension, Availability, Pricing and coordination and the quality of the up-take of bio-fertilizers may be compromised by other factors including unresolved disease and seed issues as well as changing weather patterns. Despite the fact that production and practice is challenged by the above listed problems it brought tremendous impact on farmers that are practicing. It increase yield of the legumes, soil fertility, income and yield of cereal that fellow in next cropping season.

Keywords: Impact; legumes; bio fertilizer; inoculant.

INTRODUCTION

There have been a report that Legumes like faba bean (*Vicia faba* L.) and soybean (*Glycine max* L.) is able to fix 20–60 kg N ha⁻¹ under tropical environments, but these amounts are significant for the succeeding cereal to meet the N requirement for economically attractive mean yields[1]. Farmers have been seeking ways to produce more food from the same field [2]. The incentives to intensify production increase as populations grow and land-holdings are progressively subdivided. In Ethiopia a recent report states that in the last decade land holdings have declined by an average of 1.4% per year or 14% in total(Surveys 2016). In response, farmers have innovated: the area of fallow is reduced; the use of fertilizers has increased[3]. the area planted to high yielding cereals has expanded; and the area planted to legumes has decreased[4]. As the area of arable land planted to legumes has reduced, farmers have become increasingly interested in boosting legume yields [5]. There are several ways to do this, such as using organic and inorganic fertilizers, using improved seed, or applying bio-fertilizers [6].

Bio-fertilizers are composed of a simple, milled peat/lignite base that is used to carry Rhizobia bacteria(AKLDP, 2016). At the time of planting, bio-fertilizers are usually mixed with a sugar solution

in which the seed is soaked [4]. The sugar solution ensures the bio-fertilizer adheres to the coating of the seed and that the Rhizobia quickly colonize the interior of the plant after germination (M. D. MEENA, 2012).Rhizobia-based bio-fertilizers increase the rate of root nodule formation in legumes and as a result, increase the rate of fixation of atmospheric nitrogen (N₂). This fixed nitrogen is transformed into a more useable form of nitrogen (N) that supports plant growth and productivity [5]. Critically, bio-fertilizers do not contain any chemicals that are harmful to the living soil [7]. Once the legume is harvested, the root nodule breaks down and releases the Rhizobia and nitrogen back into the soil [8]. The Rhizobia can persist in the soil or can re-infect legume plants that are planted in following years [9] the same way, the nitrogen released into the soil after harvest can subsequently be used by other crops known as ‘follow-on’ crops, and this typically results in higher yields [10].

MAIN BODY

The organization called “N₂ Africa” reported in Ethiopia, faba bean is the crop that has the highest absolute production, and the largest area cultivated. Ethiopia is also the second largest producer of faba bean in the world (after China [10]. Common bean and chickpea are also major legumes, with both a production of more

Correspondence to: Megersa Mengesha, Hawassa University College of agriculture , School of plant and horticultural science, Ethiopia; E-Mail: megersa14@gmail.com

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than 200,000 MT grain. On the world market, Ethiopia ranks 6th in chickpea production, and 14th in production of common bean [6]. Among African countries, Ethiopia is the largest producer of both chickpea and common.

In total, the area cultivated with the selected legumes is more than 1 million ha. Production per ha is low and far below the potential production of e.g. 2.9 t/ha for chickpea and 4 t/ha for common bean and faba bean.

BIOFERTILIZER

The term biofertilizer or called 'microbial inoculants' can be generally defined as a preparation containing live or latent cells of efficient strains of nitrogen fixing, phosphate solubilizing or cellulolytic microorganisms used for application of seed, soil or composting areas with the objective of increasing the numbers of such microorganisms and accelerate certain microbial process to augment the extent of the availability of nutrients in a form which can be assimilated by plant [8]. In large sense, the term may be used to include all organic resources (manure) for plant growth which are rendered in an available form for plant absorption through microorganisms or plant associations or interactions [11]. The knowledge of applied microbial inoculants is long history which passes from generation to generation of farmers [7]. It started with culture of small scale compost production that has evidently proved the ability of biofertilizer [12]. This is recognized when the cultures accelerate the decomposition of organic residues and agricultural by-products through various processes and give healthy harvest of crops [13]. In Malaysia, industrial scale microbial inoculants are started in the late 1940's and peaking up in 1970's taking guide by Brady rhizobium inoculation on legumes.

LEGUMES

The family Fabaceae (earlier known as Leguminosae) comprises more than 600 genera and about 18,000 species of cultivated plants. It is the second largest family after Poaceae (earlier known as Gramineae) [14], in terms of food and vegetable protein source, and of fodder (FAO, 2018). The sub-family Papilionoideae consists of 480 genera and about 12,000 species, of which only a few species are cultivated for human nutrition [15]. Endowed with excellent food and fodder qualities, these crops also restore soil fertility by scavenging atmospheric nitrogen, adding organic matter, enhancing phosphorus availability, and improving physical, chemical and biological properties of the soil [16]. Hence, they occupy an indispensable position in various cereal-based cropping systems in marginal and sub-marginal lands, where they sustain intensive agriculture and farming systems adopted by small and marginal farmers [13].

WHY BIOFERTILIZER

Government research institute, the Malaysian Rubber Board (MRB) had been conducting research on Rhizobium inoculants for agricultural production is constrained by population pressure, declining soil fertility and unpredictable and erratic rainfall is posing a serious threat to food production, a symptom of rainfall. Gradual depletion of N from African soils for lack of appropriate soil management [17].

PRODUCTION PRACTICE OF LEGUMES AND BIO-FERTILIZER

Agriculture Knowledge, Learning Documentation and Policy (AK-

LDP) Project, Ethiopia Technical brief in February 2016 reveals that the field assessment also confirmed that in 2015, the Agricultural Growth Program (AGP) distributed 1,600 packets of bio-fertilizer - 1,200 for chickpea and 400 packets for lentils in Gimbichu district, East Shewa to plant 300ha chickpeas and 100ha lentils. In addition to distributing bio-fertilizers, district officials confirmed that basic farmer training now includes basic information on the use of bio-fertilizers and that in Lemunabilbilo and Digelunatiyo districts, Arsi zone more than 5,760 farmers - including 1,360 female-headed households and 4,170 farmers - including 1,000 female-headed households respectively have received this training. Bio-fertilizer trainings and demonstrations have also been supported by various agriculture research centers including Kulumsa and Debrezeit. In 2015, the MBI reported total sales of 74,900 packets of bio-fertilizers for faba bean, haricot bean, field-pea, soya bean, lentils, chickpeas and mung bean or enough bio-fertilizer to inoculate seed to cover 18,700ha or 1.5% of the total arable area planted to legumes in Ethiopia. Bio-fertilizer for faba bean accounted for 24% of the sales while chickpea accounted for 26% of the sales. Improving Crop Yields in Ethiopia: Early impacts from Rhizobia-inoculated legume seed changing yields following use of bio-fertilizers.

AGRICULTURAL RESEARCH INSTITUTE

Different Rhizobium strains of economically important Pulses in Ethiopia were isolated from nodules of host legumes grown in the major growing areas. 110 strains of Rhizobium leguminosarum from *Pisum sativum*, *Vicia faba*, & *Lens esculenta*; 20 strains of Rhizobium phaseoli from *Phaseolus vulgaris*; 328 strains of *R. japonicum* / cowpea type Rhizobium from *Glycine max*, and *Cicer arietinum*; and 34 strains of *R. trifolii* from *Trifolium Sp*, were isolated at Nazret Research Station microbiology laboratory. The main objective of the collection was to obtain available germplasm resource for selection of effective strains of Rhizobium which can be used for inoculant production for regions where the soil has not enough Rhizobium cells due to some reason.

NONGOVERNMENTAL ORGANIZATIONS

Assessment of bio-fertilizers in October 2014 conducted shows that, the Agriculture Knowledge, Learning Documentation and Policy (AKLDP) and SNV launched the Cereals and Legumes Working Group in Ethiopia. Which aimed to establish a platform for policy makers, researchers, project implementer and private sector actors involved in cereals and legumes to share good practice and inform cereals and legume strategy development. They had prepared meeting on February 2015 for a presentation by Dr. Asfaw Hailemariam, Menagesha Biotech Industries PLC (MBI) on the benefits of Rhizobia-inoculated legume seed or bio-fertilizers. The following plenary discussion recommended MBI develop an evidence base for the benefits of bio fertilizers, including yield increases in legumes and follow-on cereal crops. In November 2015, the AKLDP asked a senior Ethiopian researcher to undertake a field assessment of the impacts of bio fertilizers on faba bean (*Vicia faba*) and chickpea (*Cicer arietinum*). The assessment included a literature review, meeting stakeholders and fieldwork in two PA. In each of four districts, Lemunabilbilo and Digelunatiyo, Arsi zone and Ade'a and Gimbichu, East Shewa zone. The fieldwork focused on faba bean in the two districts in Arsi zone, and chickpea in East Shewa zone. During the fieldwork, the researcher conducted focus group discussions (FGDs) with 138 farmers - including 18 women - of which 116 had used Rhizobia-inoculated

seed. Development Agents, district experts, researchers and private sector representatives were also interviewed [18]. The Field Assessment focused on understanding cropping systems, the use of and benefits of bio-fertilizers on legume and follow-on cereal crops yields, and reviewed barriers to the up-take of bio-fertilizers.

ASSESSMENT FINDINGS

The field assessment that has been conducted by Menagesha biotechnology Industry in collaboration with agricultural research institute reported that, the despite a long history of research on bio-fertilizers in Ethiopia dating back to the early 1980s, commercially available bio-fertilizers did not become available for farmers until 2010. Subsequently, the National Soil Laboratory (NSL), other research centers and some development projects have started to market and distribute bio-fertilizers. Therefore, Rhizobia inoculated seed is available to some extent in Ethiopia for faba bean, chickpeas, lentils, field pea, haricot bean, soybean and mung bean. District officials estimated average land holdings of 2.5ha in Arsi zone and 2.0ha in East Shewa zone; average family size was estimated to be six persons. Land holding averages are however rather misleading as district officials also reported a growing number of landless households, estimated at approaching 50% in some PAs. However, it was also difficult to assess the size of farm holdings accurately as used different descriptions of their land and that these were approximations e.g. 'kert' - the stretch of a farmer's stride and 'timad' - the area a pair of oxen can plough in a day. As a result, the field assessment was not able to accurately assess yield per area. Cereals continue to dominate arable cropping with a mix of wheat for bread and barley in Arsi zone and wheat for bread and pasta, and teff in East Shewa zone. Faba bean and field peas are also grown in Arsi zone and chickpeas and lentils in East Shewa zone. It was not possible to estimate trends in the planting area of pulses in Arsi and East Shewa zones, but national-level CSA 2014/2015 production data indicates that the area planted to pulses in Ethiopia is in overall decline. In the last 5 years the area planted to faba bean, field pea, grass pea and lentils has fallen by 18%, 16%, 19% and 21% respectively. In contrast, the area planted to chickpea has increased by 4% in the same period. The FGDs confirmed that farmers planted other crops including teff, linseed and mustard. Crops are used for both home consumption and sale, with farmers reporting sales of up to 60% of faba bean in Arsi zone and 80% of chickpeas in East Shewa zone. Typically, legumes are sold for higher prices than cereals. This price differential enables farmers to sell legumes and buy back larger volumes of cereals. This trade increases the availability of calories at household level. Aware of the importance of soil fertility, and soil borne pests and diseases, farmers routinely practice rotations. In Arsi zone commonly used rotations included: cereals, pulses, oilseeds and cereals; cereals, pulses, cereals and cereals; and cereals, pulses, cereals and fallow. In contrast, rotations in East Shewa zone included wheat, pulses, teff and pulses and wheat, pulses, teff and pulses. Over the last decade, population increase has resulted in increased pressure on

land holdings and a decline in the size of farm-holdings. While data is not available for the study area, IFPRI (2015) estimate that at the national level average holding size has declined by 14% in the period 2005 to 2015. This decline in holding size has resulted in many farmers abandoning the traditional practice of 'fallowing' in favor of an increase in the application rates of inorganic fertilizer. Fertilizer is used not only on cereal crops, but increasingly for legumes and oilseeds in Arsi zone.

Assessment done on the year 2015 shows that District records for bio-fertilizer use are incomplete. However, a review of available records confirmed that since 2010 farmers in Lemunabilbilo district, Arsi zone have used more than 4,550 packets of bio-fertilizer for faba bean and 1,700 packets for field-peas. Appropriately used, this is sufficient to plant 40% of the total area cultivated under these crops in the district, in the period to 2015. Similarly, records in Aed'a district, East Shewa confirm that since 2010 bio-fertilizer has been used by more than 7,500 farmers, including 100 female headed households.

IMPACT ON SOIL FERTILITY AND THE PRODUCTION

For instance the N₂ fixation potential of soybean varies ranging from 0 to 185 kg N ha⁻¹ with an average value of about 84 kg N ha⁻¹. Arega reported also knowledge about the diversity and symbiotic efficiency of rhizobia nodulating soybean in Ethiopian soils is scanty. According to the report of Agriculture Knowledge, Learning Documentation and Policy (AKLDP) Project, Ethiopia Technical Brief February 2016 on assessment conducted all FGDs (focus group discussions) under normal conditions, inoculated seed produced vigorous seedlings, strong stemmed plants, fewer sterile flowers, and plump and well filled seeds and pods show improvement. This report also shows under normal rainfall conditions, farmers reported the use of bio-fertilizers typically resulted in substantial yield increases of faba bean in Arsi zone with the highest increase of 59% recorded in Burkito-Alkesa kebele. Substantial increases were also reported for wheat follow-on crops of 40% to 168%, and barley follow-on crops of 35% to 50%, although relatively few farmers planted barley. In PAs where few farmers were interviewed, large increases in wheat and barley follow-on crops were reported consistently, but no statistical analysis was conducted. The report notes that in parallel with the development of bio-fertilizers, regional bureaus of agriculture had introduced improved agronomic practices certified seed, land preparation and pest management, that these practices may also have contributed to yield improvement. It is not therefore possible to attribute all yield improvements to the use of bio-fertilizers. Of interest, farmers in Arsi zone reported they had experimented with bio-fertilizers and used inoculated faba bean seed in subsequent plantings with a view to repeat increased yields. However, this practice is not recommended by the extension services as Rhizobia bacteria remains active in the soil for several years after the use, and the early repeat use of bio-fertilizers is therefore neither required nor advised.

Main legumes	Production (MT) grain	Area cultivated (ha)	Yield (t/ha)
Beans	244 000	263 000	0,9
Faba bean	512 000	607 000	0,8
Chickpea	213 000	310 000	0,7
Groundnut	42 000	56 000	0,8

Soyabean	6 000	9 000	0,7
Total	1 017 000	1 245 000	
Ranking of producers	Faba bean 2nd		
in the world	Chickpea 6th		
Beans 14 th			

Table 1: Production, area cultivated and yield/ha of main grain legumes in Ethiopia in 2010.

Source; Agriculture Knowledge, Learning Documentation and Policy (AKLDP) Project, Ethiopia Technical Brief February 2016* Significant difference at 95% confidence level; if the 95% confidence interval does not include zero, the difference is significant at that level. It was assumed that changes in yield after the use of bio-fertilizer could not be attributed solely to the use of bio-fertilizer. Wheat follow-on yields were recorded from farmers in Bekoji-Negesso, Lemu-Dima and Burkita-Alkesa PAs, but statistics were not calculated due to small sample sizes; barley follow-on crop yields were recorded in Lemu-Dima kebele but again, statistics were not calculated due to the small sample size; see text for further details.

*Significant difference at 95% confidence level; if the 95% confidence interval does not include zero, the difference is significant at that level. No changes in chickpea yields were recorded in Hidi or Deko PAs, Aed'a district. In East Shewa substantial increases in chickpea yields were evident in two PAs after the use of bio-fertilizer, but increases in the yields of follow-on teff and wheat crops were inconsistent, with many farmers reporting no change. They attributed this to poor quality seed, and erratic and poor rainfall. However, farmers in East Shewa zone had reduced the second 'top-dressing' of urea fertilizer from 75 to 50kgs on the basis there is more residual nitrogen after the use of bio-fertilizers; this practice is continuing with no apparent negative yield reductions. Increased chickpea yields in Katila and Habrusefu PAs. were countered by farmers from Hidi and Deko PAs (Ade'a district), who reported little or no yield increases.

IMPACT ON LIVELIHOOD

The profitability benefit of bio fertilizer can be deduced from bio-fertilizer benefit-cost analysis, which is based on the ratio of the obtainable value of benefit compared to the actual cost of the inoculum at a particular time. An enterprise will be profitable when the benefit to cost ratio exceeds 1 after discounting the gross cost and benefit. According to Mulongoy, Gianinazzi, Roger, and Dommergues[10] Yield increases have the potential to improve food security and increase household income, assuming that the cost of adopting new technologies does not outweigh potential gains. However, the field assessment confirmed that the costs of using bio-fertilizer were minimal as the cost per packet – adequate for a quarter hectare – is Eth birr 55 with an additional Eth birr 8 for sugar that is mixed with the bio-fertilizer to ensure that it 'sticks' to the seed. Farmers also reported that the additional labor required to prepare the bio fertilizer with water and sugar was less than 'the time taken to clean the soil from the wings of the plough at the end of each furrow and therefore negligible.

The report revealed that the field assessment interviewed relatively small numbers of farmers and relied on farmer-reported yields. However, a conservative estimate was that yield increases could result in an additional Eth birr 5-10,000/ ha over two years i.e. from increased faba bean yields in the first year and follow on

wheat or barley yields in the second year. Farmers also reported other benefits: increased size and plumpness or good seeds of faba bean resulting in higher sale prices, soil fertility increased as more organic matter of plants at ground-level leaving roots and nodules in the soil supporting a transition away from 'fallowing' and supporting an increase in 'productive farm holding size reduced use of fertilizer. In addition, women reported that good faba beans are easier to cook resulting in reduced firewood/biomass use. Legumes have an important role in household nutrition, in particular of poorer households who are less able to access animal sourced proteins; legumes are prepared in sauces or shiro-wot and snacks. Therefore, the full economic benefit of the use of bio-fertilizers is substantially more than the Eth birr 5-10,000/ha associated with productivity increases alone.

IMPACT ON ENVIRONMENT

Muhammad reported that Bio-fertilizers have no environmental hazards, so these could be the possible substitution of synthetic fertilizers without compromising on flax yield and it will also solve the issue of environmental pollution which is being caused by the use of synthetic fertilizers and ultimately it will be helpful in the restoration of environment

CONCLUSIONS

Faba bean – there were high levels of farmer confidence in the use of bio-fertilizers to increase faba bean yields and the yields of follow-on cereal crops. Chickpeas - the benefits associated with bio-fertilizers for chickpeas were more variable, and in some PAs, difficult to assess due to poor seed, and erratic and poor rainfall. Other benefits associated with the use of bio-fertilizers were widely reported - reduced fertilizer use, improved soil fertility, more efficient use of biomass for cooking good seed fava beans. The benefits of use of bio-fertilizer use extend beyond increased yields and income to include improved dietary diversity, and reduced workload for women. Despite the benefits, there are multiple barriers to the wider up-take of bio-fertilizers e.g. inadequate extension, availability, pricing and coordination issues, and the urgent need for the appropriate regulation and quality control.

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