Journal of Nutrition & Food Sciences

Jiri and Mafongoya, J Nutr Food Sci 2016, 6:3
http://dx.doi.org/10.4172/2155-9600.1000490

Research Article Open Access

Tepary Bean: A Climate Smart Crop for Food and Nutritional Security

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Received date: Feb 19, 2016; **Accepted date:** Apr 02, 2016; **Published date:** Apr 08, 2016

Abstract

The variability of climate demands the use of a variety of agronomic strategies and crop choices. Traditional drought tolerant crops such as sorghum are often chosen when drought seasons are anticipated. However, there are crops, tepary bean (*Phaseolus acutifolias*), such as that could help increase diversity of crops that can be grown in changed climates. Trials were conducted to determine the growth of tepary bean on station and in the field. In the field it was compared to other commonly used legumes such as cowpea, Bambara nut, groundnut and pigeon pea. Tepary bean matured in 54 days after planting, the earliest among all the legumes. A second experiment was done to determine the effects of inorganic fertilizer and rhizobium inoculation on the growth and grain yield of field grown tepary bean. This was conducted in a randomized complete block design with three replications at the University of Zimbabwe Crop Science fields. The treatments were: basal fertilizer with top dressing, basal fertilizer only, top dressing fertilizer only, rhizobium with top dressing fertilizer, rhizobium only and neither control with no rhizobium or any inorganic fertilizer (control). There were significant differences in biomass yield between the treatment with basal fertilizer+top dressing and the control ($P<0.05$). Podding showed significant differences between treatments ($P<0.05$). Results showed that a combination of ammonium nitrate with either compound D or rhizobium produced similar yield. Rhizobium with top dressing fertilizer had a mean yield of 0.57 t/ha whilst basal fertilizer with top dressing had 0.60 t/ha. We conclude that resource poor farmers, affected by drought effects of climate change, can use rhizobium for optimum production of tepary bean, in variable climate and drought seasons and still get a yield. This is crucial for food and nutritional security of vulnerable households affected by climate change and variability.

Keywords: Tepary bean; Climate smart crop; Drought; Smallholder farmers

Introduction

Leguminous crops are important in nutrition, particularly amongst resource poor people. Inclusion of legumes in the diet is important in control and prevention of various metabolic diseases such as colon cancer, diabetes mellitus and coronary heart disease. Legumes are sources of slow release dietary fibre (carbohydrates) and are rich in proteins (18%-25%). In Africa, legumes are the cheapest sources of supplementary proteins, besides being sources of minerals and vitamins. Legumes grain is an important food source used to cover dietary protein and energy requirements. They have high dietary fibre content and low lipid, with emerging evidence emphasizing the importance of legume grain as carriers of polyphenols, saponins, oxalates, lectins, phytosterols and enzyme inhibitors. Further evidence also suggests the importance of pulses in human health, particularly in prevention on coronary heart disease and diabetes.

Lately grain legumes have come out of the shadows in research and extension because of their highly valued and multiple benefits for the farmer and the farming systems across the developing world. For semi-arid regions in particular, inadequate and highly variable rainfall and short growing periods limit yield potential and create a risky primary production environment. Evidence from the Intergovernmental Panel on Climate Change (IPCC) is now overwhelmingly convincing that climate change poses one of the greatest challenges to agriculture and food security especially in sub-Saharan Africa (SSA). This is because the region is very widely recognized as one of the most vulnerable in the world due to adaptive capacity which is extremely low, which is linked to acute poverty levels and poor infrastructure, as reflected in a high dependence of rainfall agriculture [1,2]. Among the most significant impacts of climate change is the potential increase of food insecurity and malnutrition. Projections suggest that the number of people at risk of hunger will increase by 10%-20% by 2050 due to climate change, with 65% of this population in sub-Saharan Africa. The number of malnourished children could increase by up to 21% (24 million children), with the majority being in Africa [3]. These negative impacts of climate change and variability are presenting new challenges to the majority of smallholder farmers in the absence of appropriate response measures, hence the need to address the challenges. Food and nutrition strategies that bring co-benefits in terms of enhanced production of and access to food should be explored and tested. Focusing exclusively on increasing agricultural productions is too short sighted in the context of sustainable food and nutrition security under climate change because producing more food does not necessarily lead to a better access to food or to an improved nutritional status of those who need it most [3]. Adaptation is increasingly seen as an inevitable answer to the challenges posed by climate change. Diversification into new crop types and cultivars is one adaptation that has been identified as a potential farm level response to climate change and variability [4,5]. Integration of N_2-fixing legumes and other high value crops within smallholder farming systems has been identified as one of the climate change coping strategies. The potential for grain legumes as a food resource and for soil fertility replenishment has been widely researched [6-8]. Drought tolerant crops and high protein leguminous crops that include tepary bean (*Phaseolus acutifolius*) have over the years been largely ignored and neglected by research as minor crops could also be potential candidate to be included in the adaptation strategy by providing greater resilience in coping with climate change. Studies indicated that current global debates on climate change adaptation options for smallholders need also to consider benefits for human nutrition. Fageria et al. [9] reported that production of traditional crops such as small grains could be a strategy for reducing micronutrients deficiencies in humans. Finger millet and sorghum contain high content of minerals and vitamins [10]. Changes in climatic conditions have already affected the production of some staple crops. Maize (*Zea mays*. L), the staple food of Zimbabwe, is the most widespread grain crop grown under rainfed conditions in the smallholder cropping systems. As such, food security in Zimbabwe is generally defined in terms of maize but average maize yields remain low (<0.5 tha^{-1}) and continue to decline thus threatening household food security, yet in terms of nutritional importance, maize make up 49.5% of the daily calorie intake in the country [11]. Yet cereal grain alone does not provide enough nutritional value. Grain legumes complement household dietary requirements since they have high protein levels [12,13]. Physiologically, it is not only the quantity of food but also its quality and the combination into a varied, balanced diet which are crucial [14].

The human race is faced with many issues related to need for nutritious and adequate amounts of food. According to McCaffrey [15], there is no other food which has a more health-supportive nutrient profile than beans. This is because they contain nearly equal amounts of protein and fibre, which is a unique combination that is rarely found in other plant foods. This combination together with the antioxidant content of beans has proved to be a powerful weapon against today's common diseases. However, tepary bean has been noted to be better than all other bean crops. Because of the high fiber content, tepary beans have the lowest glycemic index (the rate at which a food raises blood sugar levels) of all beans [16].

Studies in the United States and Mexico suggest the importance of lectin toxins and other compounds from tepary beans in chemotherapy, halting the growth of cancer [17]. Furthermore, recent studies from the same region suggest that tepary beans are useful for treating cancer, and they could be ten times more effective than chemotherapy [15]. Tepary bean seeds were shown to contain at least two different groups of bioactive proteins with dissimilar effects on cancer cells. The lectins in tepary bean exhibited an anti-proliferative effect on non-transformed cells and on some cancer cells [18,19].

Due to the higher amounts of calcium, iron, zinc, magnesium, phosphorus and potassium, tepary bean has less digestive discomfort and gassiness as compared to other beans. Tepary beans are lower in polyunsaturated fat and in the anti-enzymatic compounds which make common beans hard to digest [16]. Phaseolus beans are amongst the major legumes for food consumption, especially in Latin America, Africa and Asia [20]. Organoleptic evaluation of tepary bean products by students native to the area of recipe origin indicated its dishes to be moderately to highly acceptable [21]. Tepary bean is mainly grown for its mature dry seeds, which are eaten after boiling, steaming, frying or baking. They are used in stews and soups, and mixed with whole-grain maize. In Uganda, the dry seeds are usually boiled and then coarsely ground before being added to soup. Occasionally, it is eaten as a green bean or as bean sprouts. The leaves are considered edible in Malawi, but are tougher than those of common bean (*Phaseolus vulgaris* L.) and take longer to cook. Tepary beans are high in protein (23%-25%) [22] and are also rich in carbohydrates according to [23].

In Zimbabwe little is known about tepary bean (*Phaseolus acutifolias*) except that is grown for subsistence by a few smallholder farmers in the eastern part of the country. With increasing climate change stress in southern Africa, tepary beans may prove to be a valuable and well adapting crop. Tepary bean has been identified as an important grain legume crop among resource poor farmers in semi-arid south eastern Kenya [24], and has been recommended as a suitable dry-season crop for the tropics [25]. Tepary bean is a short life cycle annual desert legume native to south-western United States of America and North-western Mexico [16,25]. It is a viny plant with a taproot system and nodulates well with *Rhizobium* sp. Strain R3254 fixing up to 260 kg N ha^{-1} [24]. Besides having the potential to contribute to soil fertility, the protein rich grains of legume can prevent malnutrition commonly associated with cereal based diets. Furthermore, legumes can provide market possibility, thereby providing farmers the opportunity to improve their income and livelihoods [6], which is needed to truly combat hunger and malnutrition besides an increase in total food production.

Consequently, there is the potential for the use of drought tolerant legumes such as tepary beans in agriculture to provide adequate food and nutrition security. However, there is no documented evidence on how tepary bean grows in Zimbabwe. There is need for testing the agronomic performance of tepary bean against commonly grown grain legumes. We also tested the effect of rhizobium inoculation and inorganic fertiliser application on the growth and grain yield of tepary bean.

Materials and Methods

The research was done at University of Zimbabwe Crop Science fields and at Makoholi Research Station in Masvingo Province, Zimbabwe. At Makoholi, tepary bean was grown together with other commonly grown legumes: cowpea, Bambara nut, groundnut and pigeon pea. The crops were fertilized at the known recommended rates. At Crop Science tepary bean was grown under the following treatments: Basal fertilizer only (compound D fertilizer - 7:14:7 - N: P: K); Top dressing (Ammonium Nitrate - 34.5% N) only; Rhizobium only; Rhizobium+top dressing; Basal fertilizer+top dressing; and a control with neither fertilizer nor inoculant.

Methodology

At both sites, the land was ploughed and diced. Planting was done by hand by means of a pre-marked wire cable in marking the planting stations at a spacing of 0.45 m between rows and 0.05 m within rows, with row length of 6 m. Each plot size was 27 m^2. Four seeds were hand planted per station then thinned to two plants per planting station after 2 weeks. For the rhizobium treatments, sugar was dissolved in 250 ml of water and mixed with the inoculant and mixed with 20 g of seed, and the seeds were sown immediately. Compound D was applied at a rate of 150 kg/ha before planting in the respective sub plots. Ammonium nitrate, at a rate of 100 kg/ha was applied as soon as flowering started. Mechanical weed control methods were used throughout the season to keep the crops weed free. For the tepary bean response experiment, agronomic and yield data was collected.

Experimental design and data analysis

For both trials the experimental design used was a randomized complete block design with 6 treatments and 3 replications. Data was analyzed using the statistical package R and Genstat 14.

Citation: Jiri O, Mafongoya P (2016) Tepary Bean: A Climate Smart Crop for Food and Nutritional Security. J Nutr Food Sci 6: 490. doi: 10.4172/2155-9600.1000490

Results

Tepary bean was the earliest maturing crop amongst all the legumes. Although the crops were established late, Tepary bean managed to produce a yield (Table 1), compared to other legumes.

Crop	Agronomic parameter				
	Day to 50% emergence	Days to 50% flowering	Pod yield (kg/ha)	Biomass (dry) (kg/ha)	Grain yield (kg/ha)
Tepary bean	5a	36a	151.1a	200.0a	245.9a
Cowpea	4a	51b	877.0b	502.2b	568.1b
Bambara nut	12b	46b	-	404.4b	0
Pigeon pea	11b	148c	-	493.3b	0
Common bean	12b	54b	14.8c	51.5c	227.0a
Groundnut	8b	38a	-	1,412.6d	0

Table 1: A field comparison of tepary bean agronomic performance compared with other legume crops in Masvingo Province, Zimbabwe. Means with the same letter are not significantly different from each other.

Tepary bean growth

In all the treatments germination took 5 days from the day of sowing. It took 32 days to flowering in all the treatments. The crop took 40 days to podding in all treatments. The crop took 57 days to maturity.

Tepary bean biomass yield

Figure 1 shows biomass accumulation in all the treatments. There is a clear trend of biomass increase from week 1 up to week 6 in all the treatments. However, there is a decrease in the increase in biomass at week 6 for treatments with rhizobium+top dressing and basal fertilizer only treatment. Top dressing only as well as the no fertilizer, no inoculant treatment (control) treatments showed continuous biomass accumulation even after week 6. Significant treatment differences were between the control and the basal+top dressing fertilizer treatment ($P<0.05$).

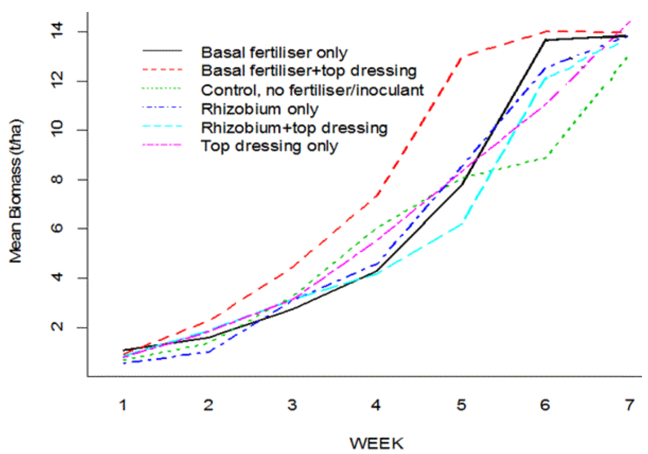

Figure 1: Effect of rhizobium inoculation and inorganic fertilizer application on tepary bean biomass yield.

Tepary bean pod number

There were significant differences in the treatments ($P<0.05$). The results as shown in Figure 2 indicate an increase in the pod number for all the treatments up to week 2 where the increase becomes steady except for treatment 4 which shows continuous increase up to week 3. Inoculating and applying top dressing fertilizer only produced the highest mean pod number whilst the lowest was recorded for the control. Analysis for each week did not show any significant differences.

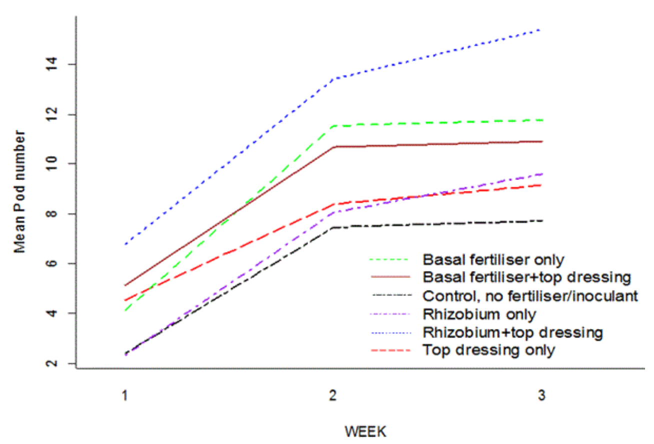

Figure 2: Effect of rhizobium inoculation and inorganic fertilizer application on the tepary bean pod number.

Tepary bean final grain yield

Figure 3 shows the final grain yield. There were no significant differences in the mean yields of basal fertilizer only and topdressing only treatments to that of the control (no fertilizer, no inoculant). Inoculant only, Inoculant+topdressing, and basal+top dressing

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treatments did not show any significant differences but they were significantly different from the control (P<0.05).

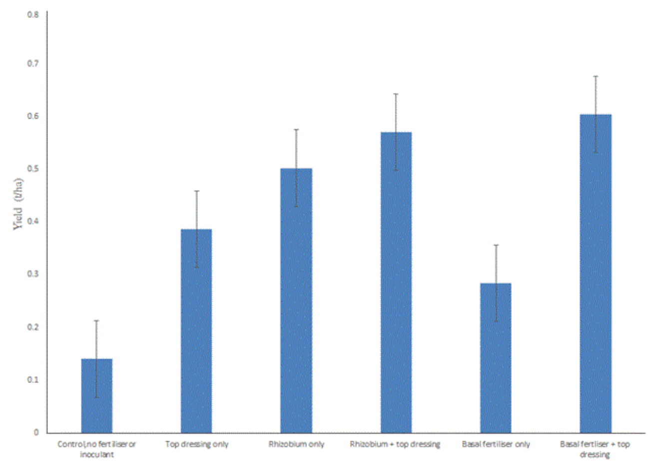

Figure 3: Effect of rhizobium inoculation and inorganic fertilizer application on final Tepary bean grain yield. Note: Error bars show LSD=0.15 (P<0.05).

Discussion

Comparison of tepary bean with other legumes

The results show that tepary bean compares well with other commonly grown legumes in the smallholder farming systems (Table 1). This is important as farmers diversify crops as a coping strategy to climate change and variability [26]. CGIAR [27] mentions important legumes for smallholder farmers as Bambara nut (*Vigna subterranea* (L.) Verdc.), Lentil (*Lens culinaris* Medic.), Chickpea (*Cicer arietinum* L.), Lima bean (*Phaseolus lunatus* L.) Common bean (*Phaseolus vulgaris* L.), Mung bean (Vigna radiata var. radiata (L.) R. Wilczek), Cowpea (*Vigna unguiculata* (L.) Walp.), Pea (*Pisum sativum* L.), Faba bean (*Vicia faba* L.) Pigeonpea (*Cajanus cajan* (L.) Millsp.), Grass pea (*Lathyrus sativus* L.), Soybean (*Glycine max* (L.) Merr.), Groundnut (*Arachis hypogaea* L.) and Tepary bean (*Phaseolus acutifolius* (A. Gray)). The majority of these pulses are already being grown worldwide, for instance common bean and groundnut, while others are concentrated in a few regions, for instance cowpea (sub-Saharan Africa), faba bean (East and North Africa, West Asia), pigeon pea (South Asia, East Africa), and mung bean (South and South East Asia). Tepary bean particularly provides hope to smallholder bean farmers affected by climate change in southern Africa as it has naturally evolved with resistances to drought and high temperature conditions [28]. Weil [16] emphasises the importnace of legumes as a cost-effective option for bettering diets of low-income consumers who cannot easily afford other sources of protein. This generates substantial benefits to the well-being of smallholder farm families. With many of the poorest countries deriving 10%-20% or more of their total dietary protein from grain legumes, the importance of low resource legumes such as tepary bean cannot be overemphasized [27]. Cereal diets, such as maize-based diets in eastern and southern Africa, are low in lysine content relative to human amino acid balance. Legumes, particularly tepary bean, are superior sources of lysine, and increase the biological value of the combined protein. The current WHO-endorsed index for protein quality is the protein digestibility-corrected amino acid score (PDCAAS) which estimates the true value of dietary protein. Experts recommend that foodstuffs of at least 70% PDCAAS should be consumed [27]. Cereals have a low PDCAAS value of about 35%, indicating their low protein quality when consumed in isolation; while a cereal legume combination in the proportions of 70/30 (weight/weight) can usually reach or exceed this PDCAAS threshold [27]. Thus, even in countries where a cereal is the dominant source of protein, every gram of legume protein potentiates another gram of cereal protein. Tepary bean seeds contain 24% protein as compared to average values of 22.3% in navy, 22.5% in red kidney, and 20.9% in pinto bean [16]. This makes tepary bean a key low cost and adaptable legume for the climate affected low potential regions of southern Africa.

Legume proteins are rich in globulins and albumins and generally have isoelectric points of 4.2 to 4.4 [28]. These protein fractions are rich in lysine and other essential amino acids but generally low in sulfur containing amino acids; therefore, they complement protein quality of cereal-based foods [29]. Several authors (e.g. in Weil [16]) have researched the production of protein isolates with approximately 90% protein from wild legumes such as lupins (*Lupinus albus* and *Lupinus mutabilis*) and Tepary beans (*Phaseoulus acutifolius*). The resulting isolates are utilized to upgrade protein concentration in foods and to impart different functionality to food systems such as water and oil absorption, foaming, emulsifying and gelation capacities [16]. This makes Tepary bean a key crop in this regard.

Other health benefits of legumes include enhanced iron concentration in beans [30]. The average iron concentration in tepary bean seed (10.7%) is higher than that in navy (6.4%), red kidney (6.7%), and pinto (5.9%) bean [16]. Grain legumes exhibit low glycemic index thus reducing the risk of obesity and diabetes [27]. A tepary bean diet, with exercise, was shown to decrease typical changes in weight gain, glycemia and lipid profile [30]. The adoption of such a program in individuals showing signs of T2D would also likely serve to protect against these physiological changes. Tepary bean seeds contain 1.8% oil as compared to values of 1.3, 1.1, and 1.1% for navy, kidney, and pinto beans, respectively. Tepary bean seed oil contains 33% saturated, 67% unsaturated, 24% mono-unsaturated, and 42% polyunsaturated fatty acids [31]. Thus consumption of tepary bean would have positive effects on colon and breast cancer and cardiovascular disease. Preliminary tests with HIV/AIDS victims fed grain legumes shows an increase in cell counts of CD4 cells, a primary element of the immune system [27]. This may imply further importance of tepary bean in diets.

Often legume crops are cultivated by women; harvests are consumed at home and sold to generate family income. In addition, tepary bean, like other grain legumes, provides on-farm agronomic benefits through biological nitrogen fixation. By complementing cereals in cropping systems of smallholder farmers, legumes can help intensify and diversify systems, particularly as an adaptation measure to climate variability and change, while improving diet and curbing malnutrition [32]. The fast growth of tepary bean not only improves soil protective cover and soil fertility, but also helps to break pest, disease and weed cycles in cereal cropping systems. Diversification of cropping choices with legumes such as tepary bean could reduce risks of harvest losses, thus increasing farmers' adaptive capacity and resilience to climate change and variability.

The climate change challenge and low soil fertility are major abiotic limitations for crop production, particularly for legume crops that are cultivated as escape crops and usually on marginal lands. Research has, however, placed legume crops to improve genetic adaptation to drought through an innovative combination of approaches such as trait based selection across different species; genomics combined with a thorough understanding of adaptation mechanisms; crop simulation modeling to help navigate the biological complexity; and interspecific crosses with desert species, *Phaseolus acutifolius*, in the case of common bean [15,33,34] This could prove to be a major breakthrough in combating devastating effects of climate induced hunger and malnutrition, particularly in hard-hit areas of southern Africa.

Tepary bean is perhaps the most drought resistant legume species in the whole world according to [16]. Gary [35] highlighted that tepary bean is recognized for its resistance to heat, drought and many diseases. It is capable of giving a notable yield with annual precipitation of less than 400 mm. These characteristics make it an ideal crop in parts of tropical production. Tepary beans' taproot is twice as long as common beans' (*Phaseolus vulgaris*), and this allows for efficient uptake of even small amounts of soil moisture [36]. The stress caused by shortage of water is believed to be the triggering factor to fruition [16]. It needs moisture to begin growing but is low on water use after it starts growth. Thus, it is an excellent xeriscape food plant [34]. Compared to common bean, it is shown to be superior in combining desirable traits that make it well adapted to drought stress [22].

Effect of rhizobium inoculation and inorganic fertilizer application on biomass yield

Basal fertilizer+top dressing had a significant effect on the biomass as shown in Figure 1. Significant differences were seen between this treatment and the control which had neither fertilizer nor inoculant. Interestingly, top dressing only treatment had the highest mean biomass yield. The basal fertilizer (compound D, 7:14:7) that was applied has more phosphorus than nitrogen and potassium. According to [37], phosphorus forms part of complex nucleic acid structure of plants, which controls protein synthesis as well as stimulating root growth. Potassium is also involved in protein synthesis [38]. The two nutrients are, therefore, important in cell division and development of new tissue. Phosphorus is also recommended for increasing early growth.

Tepary bean is known to have low root length density, which constraints nitrogen uptake [24]. However, the treatment that had compound D applied to it probably had a more extensive root network because of the phosphorus which enabled the crop to absorb nutrients from a greater area than the other treatments. It, therefore, led to the reason why this treatment had a more vigorous growth from week 1. Top dressing (Ammonium nitrate) has a higher percentage of nitrogen (33%-34%) [39] in the form of nitrates and ammonium which are readily available to the plant. It is known to increase growth [23,25,40]. The combination of basal fertilizer and top dressing consequently resulted in higher biomass yield for the most part of the plant's growth phase. Interestingly, the control and treatment 2 which had top dressing showed a continuous rise in biomass when all the other treatments were starting to show a decline in the biomass. Ammonium nitrate is known to promote vegetative growth because of its high percentage of nitrogen. Nitrogen is the most critical nutrient needed to support plant growth according to [41]. In this case it may have been the response of the crop to the ammonium nitrate.

In reference to a similar study done in Croatia, biomass yield in non-inoculated plants was significantly lower (8.01%-9.7%) compared to biomass yield in inoculated plants [42]. It is known that the synthesis of plant organic matter is promoted by inoculation.

Effect of rhizobium inoculation and inorganic fertilizer application on podding

Figure 2 shows a clear ascending trend in the number of pods for all the treatments as the weeks progressed from week one to week three. Rhizobium inoculation and inorganic fertilizer application had a significant effect on the number of pods. The crop responded to Rhizobium+top dressing more than the other treatments. Inoculation has an effect of fixing nitrogen, whilst ammonium nitrate is a source of nitrogen as well. This nitrogen may have caused the significant podding. Ammonium is a cation, so it competes with other cations like potassium, calcium and magnesium for uptake by the roots. An unbalanced fertilization might result in calcium and magnesium deficiencies. Potassium uptake is less affected by the competition [33]. Calcium is an important nutrient in the formation of pods and if in any case it was rendered unavailable by excess nitrogen then it might be the reason why the treatment with top dressing only had a low number of pods. An important point to note is the continuous increase in pod number which is shown in Figure 2 in all the treatments. The yield might have been a bit higher than the ones noted if the crops were left for some more weeks to reach their maximum capacity of podding. However, the weather conditions were not favorable as there was continuous rainfall which would have caused further losses in grain yield.

Effect of rhizobium inoculation and inorganic fertilizer application on final grain yield

The highest final grain yield was recorded for the treatment with basal fertilizer+top dressing and this was not significantly different to the treatment which had rhizobium+top dressing and the one with top dressing only as well as rhizobium only as denoted by Figure 3. This observation contradicts with a research done in Kenya in which nitrogenous fertilizer did not have significance on the yield of tepary bean [24]. This might mean that the effects of the rhizobium and basal fertilizer are the same if combined with ammonium nitrate. Basal fertilizer provides the plant with starter nutrients that are needed for early growth. However, according to [35] phosphorus does not increase grain yield. The nutrient may have played an indirect role of promoting a good root network which enabled the crop to absorb nutrients efficiently. Biological fixation of nitrogen by rhizobium contributes large amounts of plant usable nitrogen to the soil nitrogen pool [43]. This plant usable nitrogen might have an effect in the early growth of the crop which is equally as good as that provided by the basal fertilizer.

The treatment that had basal fertilizer only yield was not significantly different from that of the control. Compound D is known to be effective in the soil for the first four weeks after application. The low yield for this treatment may be attributed to this. By the time the crop was harvested basal fertilizer might have been exhausted and the crop was already thriving under nutrient deficiency conditions. Ahmad [44] states that balanced use of inputs like fertilizers and moisture is essential for improving harvest index of grain crops. Yields obtained in this study consummate with those obtained elsewhere, estimated to reach 200 kg to 900 kg per hectare; variations come as a result of differences in sowing density and rainfall [31].

These results show that tepary beans are a resilient food resource, able to survive in drought climates. This agrees with Albala [23] who reported that the plant is highly drought and disease resistant, and provides a quick harvest that is high in nutritional value. They are also small and develop quickly, soaking up a lot of water early on and protecting it within a hard, thick skin [36]. During the course of the experiment, at both sites, Tepary bean was not attacked by mildew or smut (*Xanthomonas phaseoli*), which commonly attach other grain legumes. This is supported by Gary [35] who concluded that the fact that tepary bean is not attacked by mildew or smut diseases makes it a useful species for improvement of other food legumes via genetic introgression. It is, therefore, expected to have significant potential for introduction into semi-arid areas [35]. IPCC reported that, with climate change, droughts would become more frequent and more severe in southern Africa and drought affected areas are projected to increase in extent. Drought ranks as the single most common cause of severe food shortages, particularly in developing countries, and represents one of the most important natural triggers of malnutrition and famine affects the four dimensions of food security, availability, stability, access and utilisation [45,46].

Conclusion and Recommendation

Tepary bean is among the most drought resistant legume species that can be grown in the smallholder drought prone farming areas. It is capable of giving a notable yield with annual precipitation of less than 400 mm. Furthermore, small-holder farmers can be recommended to grow tepary bean and inoculating it with rhizobium. Further research on rhizobium strain efficacy is recommended to determine the strain that has more effectiveness in terms of giving a higher Tepary bean yield. There will be need for further testing of other agronomic practices particularly planting dates and densities to determine the optimum yield. It is further recommended that a similar study be carried in other soil types to establish the effect of different soils on yield. Even though tepary bean is known to produce a nutritious seed that is suitable for human consumption composition of tepary bean seed produced in Zimbabwe is not known. There is need to characterize the protein and mineral composition of tepary bean seeds and to compare the composition of mature raw tepary bean seed to some of legumes commonly grown by smallholder farmer in Southern Africa.

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