The research and development progress and suggestion in graspea, would help re validation of the crop in total production. There is less to invest on adaptability of the crop once the utility values are stepped well. The crop is promise of the climatic wave era, that is now. Nature has already trained grasppea, how hardy it should be in adapting extremes of climatic and nutrient variability. This information sold as is evidenced from the so far efforts and historical blueprints. This old crop will have to be promoted to make use of in a safe way. Science, is demanded to formulate grasspea a safe to use, valuable to sale and nutritive to feed.

Dr Asnake Fikre has served Ethiopian Institute of Agricultural Research for more than 17 years, before transferred to ICRISAT as regional chickpea breeder. Currently Dr Asnake is working on chickpea and associated legumes improvement for Eastern and Southern Africa /ESA/Region.

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Research and development with grasspea (*Lathyrus sativus* L) in Ethiopia: past and future

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Dissertation: Improving the nutritional quality of *Lathyrus sativus* L. (grasspea) for safer consumption

Summary

Grass pea (Lathyrus sativus) is an important pulse crop in Ethiopia and other parts of the world that is poorly managed and yet demonstrating improving performance. Often grasspea is grown on farmlands with low fertility or on problematic plots. Research on grasspea is at a lower level compared to other crops with respect to investment, technology generation, popularization of existing packages etc. There is an enormous potential for grasspea in the climate change target agriculture of today. With the recently increasing importance of the crop in Ethiopia and in other parts of the world it is crucially important to enhance the research and development of the crop for better benefit to the farmers. This central issue will be highlighted in this review.

(Reflections in this book are account of the author)

This book is dedicated to lathyrism victims of the world for science limitation.

1. Introduction

Global change as a function of climate, economics, technologies and social dynamics is a gigantic evolution affecting billions of citizens and biodiversity. The success of the human race on this globe has been the result of continuous innovations. However, of all challenges water and food supply have been a matter of survival or extinction. Already one billion human population is on forced chronic hunger or malnourishment. The planet is by no means ready to nourish the newly coming four billion in four decades time from the present agricultural resources, let alone the present malnourished billion. The development of agricultural sciences needs to cope. As the change in climate seems to accelerate, the research on food crops that are tolerant to drought and adverse environments needs more inputs. As the change in climate seems to accelerate, the research on food crops that are tolerant to drought and adverse environments needs more attention and support. Developing the genetic basis of climate responsive or climate proof crops like grass pea *(Lathyrus sativus)* is becoming an apparent choice.

Ethiopian agriculture has long been very unstable in response to changing climatic factors particularly drought. Drought is a phenomenon commonly manifested by either a delay or the reduced length of the main rainy season, or insufficiency of the precipitation. In the face of such climatic events or fertility deterioration of the soil grass pea is the farmers' choice as an insurance crop or even a survival crop. The productive and efficient nitrogen fixing crop needing little or no inputs nor management, is a blessing for most resource poor farmers. The production of the crop is on the increase (Table 1) both in area coverage and production volume at the expense of other eco-competent crops (CSA, 1990-2009). Between 2007 and 2015, area has increased inconsistently but on a positive gains, where we had the highest record in 2012 hitting 205000. Yield on the otherhand showed positive and consistent increase with average gains of 16.5kg/ha/year or by 1.3% in each year. This might indicate the improvment of management made to the crop, at least on the field husbandry. On the otherhand the total production has less affected by the variability in the area, due mainly componsated by yield gain per unit area.

Table1 : A recent production area (ha) and volume (t) of grass pea production in Ethiopi

Year	Yield (kg/ha)	Production (t)	Area /ha/	Producer HH (000)

2007	1260	185490	147172	561
2008	1265	202126	159731	774
2009	1504	204020	135658	670
2010	1533	200943	131043	673
2011	1699	305575	179866	
2012	1585	325581	205374	948
2013	1873	317322	169441	829
2014	1837	251439	136883	744
2015	1808	287674	153105	783

Despite the poor management, negative promotion and marginal inputs (Fikre, 2008), the increase in volume of the crop indicates the fitting power of the crop in calamities of climate change and natural resource deprivation. A number of prior reports highlighted the fact that grass pea is amongst the important pulse crops exceptionally surviving low inputs (Urga et al., 2005; Fikre, 2008), biotic and abiotic stress (Spencer, 1989; Ludolph et al.,1987, Haimanot et al., 1990, Campbell et al.,1997, Croft et al., 1999;), and adverse ecological and environmental conditions (Haimanot et al., 1990; White et al., 2002; Lu et al., 1990; Campbell et al., 1997; Noto *et al.*, 2001; Tadesse and Bekele, 2001; ReTekle Haimanot et al., 2005; Fikre et al. 2011).

The current increasing productivity which is now 1.8 t/ha, that has never been attained by high input cereals or technology supported legumes; and put it as hardy crop of choice for survival. Grasspea is now among top three productive pulses in the country (Fikre et al., 2006).As global trend, grasspea, has more vertical gains than its horizontal expansion.

The increasing trend in the production also suggests that the consumption, in which case the crop is used as a staple food during periods of food insufficiency, and transaction value of this crop has enormously increased. Today the transaction value of shiro, popular curry used with injera, in cities like Addis, is so huge and competing and replacing many other pulses. Shiro is the healthier food type of grasspea studied so far.

Having a primary center of diversity in Ethiopia (Thulin, 1983; Urga et al., 2005) the adaptation of the crop in the various sub-climates of this country has gone on since early civilization. Its reintroduction and expansion and consumption in European and Asian countries is well documented (Polignano et al., 2005; Getahun et al., 2005; Milczak et al., 2001). Based on FAO grass pea production statistics (1996-2007) Ethiopia accounts for 75.3 % and 9 % in area cover and 85.4 % and 8 % in grain production of Africa and the world respectively (Fikre, 2007). Looking the 2014 FAOSTAT, it missed Asian countries and synonym of grasspea is vetch.

Hence, there is a confusion on the data basis if vetch stands of Lathyrus sativus or Vicia sativa that commonly produced for animal feed. However, there are some 30 countries producing grasspea this day of course for different purposes under different utilization, as some have been portrayed on the Figure 1, below. This review highlights the need for research to better understand the tolerance of grass pea to drought and adverse environmental conditions and for the better use of this underexploited crop that is a vital resource for millions in the world including new introductions.

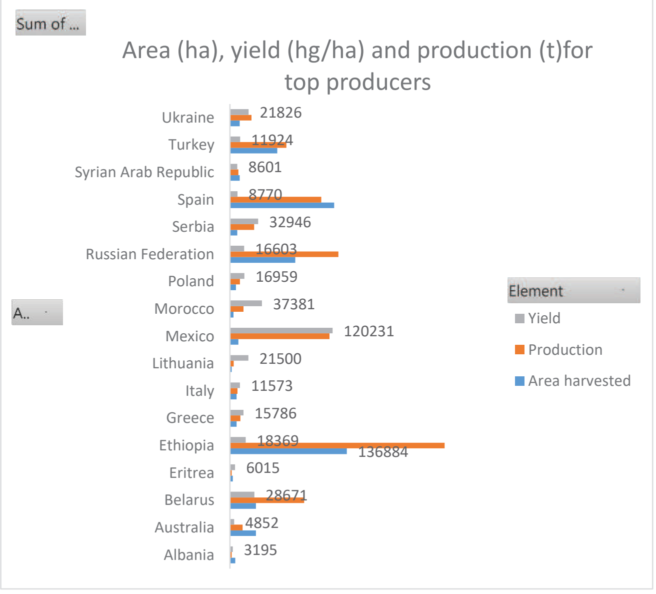

Figure1: some major grasspea/vetch producing countries 2014

2. Significance of Grass pea in Ethiopian agriculture

2.1. Cropping system

Ethiopian agriculture is characterized by mixed farming, both crop and animal husbandry are practiced together under small farm holdings. This is common in areas where grasspea is cultivated. The soil in grass pea growing areas is dominated by vertisol of volcanic origin where both water logging and water stressed derived soil cracking occur extensively. In prevailing of those two end extremes the choice of crop as the mitigator is remaines as best option.

There is agro-ecological overlap of grasspea by chickpea, lentil, faba bean, field pea and cereal crops. This means that expansion of one of these crops implies the reduction of the others, in favor of complementarity choice by condition. The significance of the expansion of the “neglected” grasspea (Table 1) in such scenario demonstrates, nothing but, the increasing importance of this crop as change adaptive, multi-stress tolerant and economically viable.

The significance of grasspea among legumes is also worth mentioning. The production proportion of grasspea has long-back taped about 10% (Table 3, Figure 2) of the principal legumes. Unlike others, there is no solid evidence on the export of raw grasspea. This might support that grasspea is serving a kind of staple food not only during famine (Ashutosh Sarker –in press) but as well become adapted staple food in normal times.

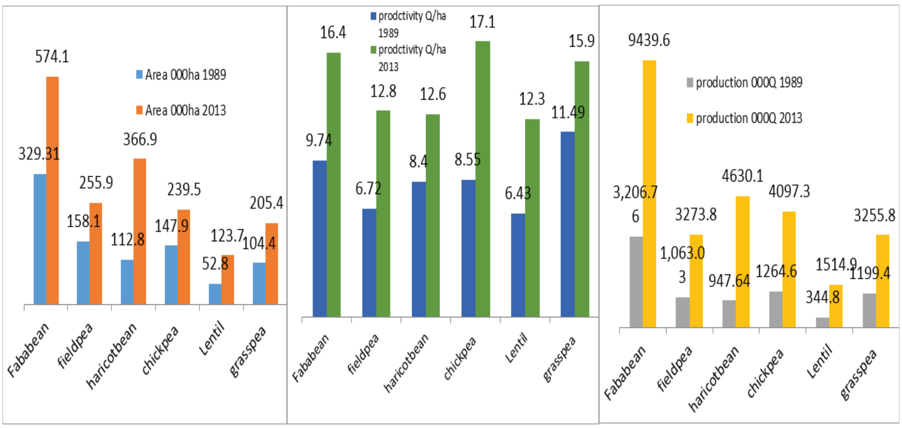

Figure 2: Progressing trend in area, productivity, and production of grasspea among principal field legumes of Ethiopia

Table 2: Current account of grass pea among major pulses grown in Ethiopia (CSA 2015)

	No of holders	Area ha	Production Q	Yield Q/ha	Remark

pulse	8,196,752	1,652,844.19 (13.24%)	27,692,743.11 (10.38%)		Average yield of crop cluster basis: 21.4Q/ha-field crops/25spp/ 23.2Q/ha-cereals/8spp/, 16.7Q/ha-pulses/11spp/, 9.2Q/ha-oil crops/6spp/)
Fababean	3,568,225	443,966.0	8,486,545.69	19.12	
Fieldpea	1,618,596	221,415.67	3,233,901.34	14.61	
White haricot bean	926,660	113,249.95	1,597,394.84	14.11	
Red haricot bean	2,455,096	244,049.94	3,804,994.53	15.59	
Chickpea	1,171,576	258,486.29	4,726,113.88	18.28	
Lentil	686,415	100,692.74	1,339,336.4	13.30	
Grasspea	783,184	159,105.68	2,876,743.76	18.08	
soybean	140,263	38,166.04	812,418.33	21.29	
fenugreek	559,787	29,837.65	356,537.64	11.95	
Mungbean /masho/	136,392	27,085.92	271,589.80	10.03	
Gibto/lupines	87,910	16,788.20	187,166.88	11.15	

Grasspea is often produced as land filling, where its hardiness make production possible. Among those areas are marshy landscapes, water retreat plains, marginal fertility landscapes, drought stricken farms. However, there are significant portion of croplands, where grasspea serve as precursor for main cereals. The great vertisol plains in central highlands of the country, including the paddy rice plain of Fogera is subject to grasspea in the crop rotation.

Interestingly, all the seed used for sowing are from the farmers' own cultivars. So far only one improved grass pea variety named 'wasie' is released in Ethiopia that has reached a very insignificant number of farmers.

Table 2: Grass pea in per cent of total pulses grown in Ethiopia

Cropping season	Area %	Production %
2008/9	10.4	10.3
2007/8	9.6	10.4
2006/7	9.1	11.6
2005/6	9.5	11.5

Although the yield per ha is far from optimal, it surpasses most of the better managed pulse crops in the country. Nonetheless, with the introduction of advanced production technologies (improved varieties and production packages) some of the other pulses are showing enormous advance in productivity. For example in the last five years the productivity of lentil and chickpea has almost doubled as promoted from 0.5 t/ha and 0.8 t/ha to 1.1 t/ha and 1.3 t/ha respectively (CSA, 2000-2009). In grass pea a considerable difference in yield between the national average (~1 t/ha) and the productivity under improved management (4 t/ha) was demonstrated for farmer cultivars in Ethiopia (Fikre *et al.*, 2006). In spite of the many advantages this adaptable and multipurpose crop can offer, it is inadequately exploited and studied.

The production of pulses is normally in rotation with cereals. Cereals account for tenfold the size of pulses both in production and area. Double cropping is also a common practice for chickpea and grasspea after the principal cereal crop is harvested. The driving underlying principle in this cropping pattern is the total production increment per unit area for the same season. In this regard, it is noted that grasspea, like other major legumes saves about 30% of the nitrogen for following crop. This value is also accompanied other side benefits like biotic stress breakage, soil condition improvement and weed suppression.

2.2. Food and feed benefits

Grass pea can be a promising agricultural crop of the future and if a safe mode of consumption is established. Although grass pea is considered an insurance crop by the farmers, and must have saved many lives during droughts, nutritional research into safe consumption received less attention than alarming reports on neurolathyrism occurring after prolonged overconsumption of the seed during famines (Diasolua Ngudi et al., 2012). As a stress tolerant food crop, grasspea is a very promising source of protein, carbohydrate and minerals for drought prone marginal lands. The seeds contain an average of 27 % protein, 0.6 % fat, 58.2 % carbohydrate (about 35 % starch) (Duke, 1981; Williams *et al.*, 1994; Urga *et al.*, 2005; Vaz Patto *et al.*, 2006; Fikre, 2008). The seeds contain 1.5 % sucrose, 6.8 % pentosans, 3.6 % phytin, 1.5 % lignin, 6.69 % albumin, 1.5 % prolamine, 13.3 % globulin, and 3.8 % glutelin. It has also a good level of essential amino acids, except for tryptophan, methionine and cystine which commonly are deficient in legumes. The traditional food processing and consumption of grass pea in Ethiopia, unlike other pulses, is very diverse (Table 4).

Table 4: Food preparations and consumption tradition of grass pea

Country	Traditional grass pea food	Brief description of the preparation for consumption	Reference
Ethiopia	*Shiro wot* (sauce)	Sauce prepared from roasted *L. sativus* powder and eaten with pancake (*injera*) or unleavened bread (*kita*)	Haimanot *et al.*, 1993; 1995; Getahun *et al*, 2005; Urga *et al.*, 2005; Fikre, 2007
	Kik wot	Roasted, de-husked and split *L. sativus* seed made into sauce	
	Kollo (roasted snack)	Roasted seed directly consumed	
	Nifro (boiled snack)	Boiled seed eaten directly	
	Kita (unleavened bread)	Unleavened bread usually made from unfermented dough of *L. sativus* consumed in time of acute food problem	
	Eshet (green peas)	The seed in the green pod before maturity, usually consumed by children while tending the farm field	
	Elbet (sauce)	Powder of roasted grass pea well spiced and fermented, occationally consumed like in fasting periods of coptic Christians	
	Seteto	Baked kitta after fermentation of grass pea dough usually on clay pans	
	Injera (pancake bread)	Fermented and baked, from powder usually adulterated with cereals	
Bangladesh	*Dahl*	Aqueous slurry cooked with spices	Hussain, 1994
	Curry	Cooked with vegetables and/or fish	
	Bora	Paste ball with onion and spices, deep fried in oil	
	Chapatti /roti	Unleavened bread of *khesari* powder	
	Khichuri	Cooked with rice in 3:1 ratio	
India	*Chapatti*	*L. sativus* flour is routinely used either alone or in combination with wheat, barley or Bengal gram as *chapatti*	Malek, 1998
	Ghotu	*L. sativus* flour and rice in ratio of 3:1 cooked in water to form a stiff porridge	
	Dal (soup- like dish)	Cooked whole split or de-husked grains into a soft semi-solid form and eaten as side dish with rice or *chapatti*	
	Snacks	As substitute of pigeon pea and chick peas	
W.Asia	Green vegetable	Young vegetative parts plucked (4-6 cm) and cooked as green vegetable also rolled and dried for off-season use Green pods/seeds eaten directly or salted, cooked and consumed as snacks (India, Bangladesh, Pakistan)	Campbell, 1997

Source: compiled by Asnake Fikre (2007)

Besides being an important food for humans, grass pea provides feed. Particularly in the developing world, several studies reveal that grass pea can be an important feed input for livestock including fowl. Chowdhury *et al.* (2005) studied the nutritional value of grass pea (0.4 % ß-ODAP) for growing and laying pullets and concluded that inclusion of 10, 15 and 20% of grass pea in the feed had no negative effect. Tadelle, et al. (2003) demonstrated that grass pea can be used as a replacement for commercial protein and energy source for poultry feed with minimum processing. A study of the nutritional assessment by Gizachew and Smit (2005) indicated that the concentration of Ca (16 g/kg), Na (274 mg/kg) ($P <$ 0.001) and Fe (152 mg/kg) ($P < 0.05$) in grass pea haulm exceeded that of teff straw, while the reverse was noted for P and Mn ($P < 0.001$). Grass pea grain had high concentrations of crude protein (280 g/kg) and Fe (78 mg/kg) having lower C: N ratio (1.06) but was in general deficient in Cu and Na for feed purposes. Fikre (2007) indicated that the cheap sources of grass pea grain being used for small holders fattening pays back a high net profit.

2.3. Environmental stress and grasspea

Ethiopia has since long suffered from recurrent droughts, some of which gave rise to famines. Drought-triggered famines have been the prelude to neurolathyrism epidemics in the past (Getahun et al., 2005; Haque, 1997). On the one hand, during drought-triggered famine grass pea remains as the only affordable choice of food as all other crops fail and it must have saved millions of lives. On the other hand, prolonged overconsumption of grass pea can suddenly cause irreversible neurologic disease with crippling of the legs or neurolathyrism. The most probable cause of this is the neuro-excitatory amino acid β-ODAP present in the seed in varying concentrations depending on genotype and environment. The crop is invaluable as an insurance crop that bridged the gap between a failed crop due to drought and the upcoming season crop.

It was suggested that β-ODAP might be important for the plant by acting as a defense to various environmental stresses (Lambein *et al.*, 1990; Haque, 1997). This β-ODAP might then contribute to the hardiness of the crop. Hence, the plant apparently produces less β-ODAP in the seed under optimal growing conditions than when it grows under marginal conditions. Another important point is that under favorable growing conditions, the plant produces more pods and seeds with reduced β-ODAP concentrations, possibly as a result of a dilution effect. In identical unstressed conditions, plants with only 10 pods contained 59 % more β-ODAP in the seed than plants with 100 pods (Cocks *et al.*, 2000).

From a similar study by Cocks and co-workers (2000) and Asnake et al., (2011) it was demonstrated that the effect of stress due to climatic factors (temperature, rain fall, sunshine hours) on β-ODAP accumulation was apparently stronger (doubling) when confronted by the plant during post-anthesis than during pre-anthesis. In sum, the negative health impact of grasspea is apparent only under moister stressed grasppea consumed by nutrient stressed people, which is case of bad-combinations. These results can contribute to the information needed for better agricultural management practices to produce a grass pea crop in more suitable agro-ecologies that may yield seed with better nutritional quality.

3. Grasspea Research

The biological, agronomic, biochemical, pathological aspects of grasspea have been studied since four to five decades. Unlike other crops, however, much of the works have been overwhelmingly and blindly driven to end-up with the toxic component study. This particular issue has compromised the progress I research and development of the crop, and kept away its useful potential from disclosure. Very limited genetic progress happened in developing stable low ODAP lines; and it is inferior result compared to crop management by environment effect. Still there is no universal understanding on how to go forward using the environmentally hardy legume resource of the world.

In Ethiopia Debere Zeit Research Center, has been responsible to undertake research, which in the last 20 years could release only one variety. As all benefits of the crop should have been checked at the point of its toxicity, it does not matter all other technology options in agronomy, crop management, consumption etc have all been compromised high. Currently there is low and disappointing priority and budget allocation for grasspea research in Ethiopia.

3.1. Genotypic and phenotypic basis of study for favorable traits

Ethiopia is secondary center of diversity for grasspea. The genetic resources of grasspea in Ethiopia is both from landraces and introductions. Ethiopian Biodiversity Institute (EBI) and Ethiopian Institute of Agricultural Research (EIAR/EARO) are pioneer reference of the genetic resources of grasspea. Hundreds of germplasm resources are conserved with in EBI. Diversity study on landrace collection have been demonstrating existence of different performing ecotypes growing in different parts of the country. This is good opportunity for the research program in improving the agronomic and important traits of the crop.

For its linked health concerns, the crop has been banned by some countries, however, it keep its momentum in no willing world. So this review is to indicate attempts undertaken under sub-standard investment. Through national research programs, universities and Nutrition Institute have been undertaking studies on biochemical and social aspects of grass pea. In the last three decades, however, only one variety could be released with reasonable qualities. Likewise, information flow, even if non-harmonized, on different aspects of the crop use and biological aspects has been generated and disseminated to the wider public.

Through morphological and molecular diversity studies, Tadesse and Bekele (2001) have demonstrated that there is enormous variability among different ecotypes of grass pea growing in Ethiopia. It was also shown that some cultivars, including the released 'wasie' that have been produced through traditional breeding are superior in productivity. These lines have produced up to 4 tons of grain per hectare as compared to land races whose productivity is still about one ton per hectare (Fikre, 2008).

A similar study also demonstrated that β-ODAP synthesis is negatively correlated to productivity under various environments. Observations on pathological events in Ethiopia grown grasspea showed that intermittently variable climatic conditions favored foliar fungal diseases that potentially could be a problem.

3.2. Biochemistry

The classical reference of biochemical pathways proposed by Lambein et al (2007) after its identification reported by Rao et al. (1964) as ß-N-oxalyl-L-α,ß-diaminopropionic acid (ß-ODAP) as causative of lathyrism is impotant. This being high pillar of grasspea identity since long. This marked remarkable understanding of this biosynthate in the plant.

A number of studies have been undertaken focusing on the biosynthetic characterization and the quantification of β-ODAP content in the plant. Since its identification in 1964, these biochemical and toxicological studies obsessed scientists more than any other component of the crop improvement. The findings of all the biochemical analyses particularly with β-ODAP level revealed that it is variable (Fikre, 2008; Urga et al., 2005) among different lines or collections (Urga et al, 2005; Fikre et al., 2006; Denekew and Tsega, 2009), among different processing methods suggested as sources for safe food (Getahun et al., 2005, Fikre, 2008), among different extraction methods studied (Girma, 1999) and also among different growing environmental stresses (Fikre, 2008; DZARC, 2001-2004) triggering the biosynthesis.

From food and feed perspective a significant variability in β-ODAP level between improved varieties (Wasie, ILAT-LS-LS-B1, ILAT-LS-LS-B2) and local cultivars is reported in a magnitude of doubling for forage, grain and straw components of grass pea grown in Northwest Ethiopia.

3.3. Nutrition

Grasspea is competitive in nutritional composition that benefit both human and animals. Some of the amino acid are far superior compared to other commercial legume including soybean (Figure 3). Hence, grasspea is sensitive to nutrition elements as part of the benefit.

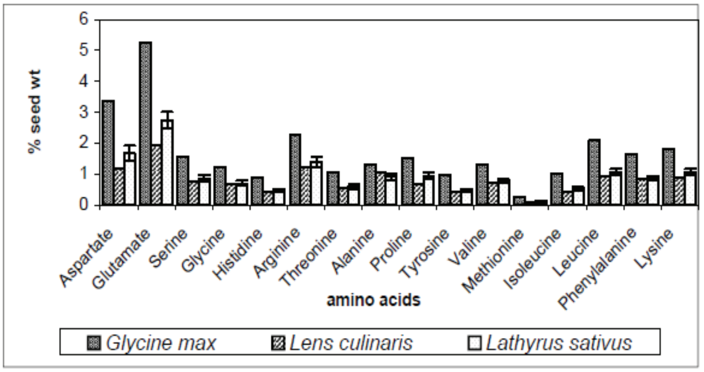

Figure II.3: Average protein amino acid profile in *Lathyrus sativus* (mean of nine genotypes), compared with lentil (*Lens culinaris*) and soybean (*Glycine max*)

Source: Asnake (2008)

Extensive studies on the food and feed consumption of grass pea in Ethiopia have demonstrated different modes of consumption. The nutritional values (nutrients, protein, calories, etc.) of grass pea grown in diverse agro ecologies have been studied by different groups (Urga et al, 2005; Fikre, 2008; Girma 1999) and quantifications reported. The range of these components has been found sufficient and adequate in most cases. Factors of food safety have been described or suggested almost in an exhaustive way.

Unlike other food legumes, grass pea is used as a staple food. It is an important source of dietary proteins, calories and minerals for humans (Urga et al., 2005). Grass pea is a nutritious and stress-surviving crop. Seed of Lathyrus sativus is prepared into traditional dishes after dehusking and parching or milling. As a drought tolerant food crop, it is a very promising source of protein, carbohydrate and minerals for drought prone marginal lands with seeds containing an average of 27 % protein, 0.6 % fat, 58.2 % carbohydrate (about 35 % starch) (Urga et al., 2005; Vaz Patto et al., 2006). The seeds contain 1.5 % sucrose, 6.8 % pentosans, 3.6 % phytin, 1.5 % lignin, 6.69 % albumin, 1.5 % prolamine, 13.3 % globulin, and 3.8 % glutelin. The concentration of essential amino acids in g per 16 g of N (equivalent to 100 g of protein) reported were: arginine 7.85, histidine 2.51, leucine 6.57, isoleucine 6.59, lysine 6.94, methionine 0.38, phenylalanine 4.14, threonine 2.34, tryptophane 0.40, and valine 4.68 (Duke, 1981; Williams et al., 1994). Like other cool season food legumes, grass pea is highly deficient in methionine, cysteine and tryptophane. Nonetheless, Grass pea has been reported to have toxic metabolites causing irreversible crippling in humans if utilization procedure is abused.

From all research progresses, it is concluded that synergistic interaction of social, bio-physical and processing factors can make grass pea a safe food to consume. The studies made by the Ethiopian Institute of Nutritional Research, Getahun (2004), Urga et al., (2005) and Fikre (2008) have revealed the nutritional competitiveness, safety and quality attributes of grass pea foods in Ethiopian context as commendable to be popularized through extending information.

3.4. Agricultural sustainability

The contribution of grass pea to the fertility status of the soil is very well known by farmers, but has never been explored well. Preliminary studies indicate that as a precursor crop it saves about 30% nitrogen for the following crop. One remarkable advantage of grass pea is that it keeps the soil moist and less eroded by wind during the drier period of the year, as it is the only crop that stays green in that period. In dry spell, farms would be in green cover, and that green is commonly grasspea. Evidently it is often noticed that the performance of the following crop becomes more rigorous, productive and healthy, which explains the additional merit of grass pea as a result of residual nitrogen and possibly from recycling of other nutrients from the deep penetrating roots mining deep down in the moisture level. There is also practice of green cultivation where the greener grasspea is pulverized into the soil system. This helps to enhance soil condition from easily degradable biomass and its rehizobia that easily can easily release effective nutrient media for upcoming crop.

3.5. Socio-economic value

Apart from chemical and toxicological studies on β-ODAP, extensive epidemiological studies have been done in Ethiopia (Haimanot et al. 1990; Getahun et al. 1999) on grasspea. One of the trigger for the study being the epidemics of neurolathyrism of those days. The socio-economic studies have clearly demonstrated what social factors are critically linked with grass pea overconsumption with potential hazardous consequences, and what factors predisposes all sources of anomalies sparking from grasspea consumption?

In his 'carte blanche' editorial in the issue of 'European Grain Legumes Magazine' dedicated to *Lathyrus,* Lambein (2010) rephrased earlier findings ''only recently, epidemiology discovered a link with illiteracy, poverty and young age as risk factors for neurolathyrism, and fermentation of the seeds and consumption together with cereals, onions and ginger as protective factors. From long time studies, it was conclusively reflected that the low level of essential sulfur amino acids in grass pea seed is probably as important as β-ODAP as potential cause of neurolathyrism. Neurolathyrism affected hundreds of thousands in the world since long. Most victims are those either in mis-perception or poor understanding of the reality about the crop. Based on status of the manifestation, neurolathyrism can be classified into four symptomatic stages.

I. -Spastic gait with no stick and no Babinski sign

-Only ankle and joint movement restricted by muscle spasm

-Rigid walk on ball of the feet, tilting pelvis leading to jerky movement

-More visible when running

-It remains or passes to the next stage

II. -Severely affected patients

-With adductor spastic walk, scissors gait

-Ankle clonus and Babinski sign present

-One crutch/stick needed for maintaining body balance

III. Aggravated condition of stage II

-Muscular stiffness and bending at knee joints

-Spastic cross adductor gait

-Ankle clonus and Babinski sign present

-Severe muscular rigidity, patients need two sticks for support

IV. Most severe cases

-Patients develop chronic paraplegia in flexion of knee joints

-Extreme stiffness of lower limb and considerable bending of the knees (contracture)

-Arms are strong and pyramidal signs present

-Cannot walk upright hence crawling or bed ridden

In a well-balanced diet grass pea can be a healthy and safe food, but legumes are not intended as staple food and neither is grasspea. The unique qualities of grasspea as resistant to biotic and abiotic stress, high nitrogen fixation and adaptable to high and low elevation and poor or contaminated soil (considered for phyto-remediation) should be better exploited by molecular breeders to arm the world against climatic changes and pollution, and *Lathyrus sativus* should no longer be treated as a pariah.''

Hence, all the studies indicated the importance of the social factors behind all the un-intended health outcomes. One of the key assertion for grasspea ass safe food, is dependent on the social factors understandings on safe utilization of the crop.

4. Development pathways

The agricultural setup is reluctant to consider grasspea as crop of primary importance. Neither, do research derived technology options strongly coming up in building the crop as builder of the crop sector at large. There are limitations on all value chains of the crop, and yet the crop signify itself as self-appointee/ volunteer. The choice between death and grasspea eating as lifesaving in desperate drought condition, is choice of the subject. Many studies found what precaution need to be taken to use the crop safe and non-risk. On the other hand, it shouldn't be not be undermined, how consumers get essential amino acids and other nutrients better composed in the plant.

4.1 Policy support of the crop development

In Ethiopia grasspea is neither promoted nor banned, so it follows its natural course. However, there are data basis on the crop cover and production at district level. Despite the increase in area, volume and productivity, the policy towards grasspea need to come up with defined stand. Today farmers are getting about two tons of grasspea and of this an estimated of ~75% is being sold. The market structure of the crop is layered between assemblers and retail salers, and between raw and processed (split, powdered etc) salers. The market product movement with in the country is so high, among small and big towns countrywide. It is estimated an equivalent of some 20000 can be generated from a hectare of land; and its production cost is as minimal as it is healthy and less protected crop during the field growth.

4.2 Extension service and promotion

It pressing to enhance the seed and technology system of legumes in Ethiopia. Despite the fact that only less than 105 of the whole grain legume system is receiving improved seed supply, while the rest more than 90% has to survived on producer farmers sources (own saved, exchanged, non-seed sources etc). The recent initiatives on community seed system along with the quality declared seed endorsement, apparently has start improving the volume of supply and access of legume seeds to a certain degree.

Considering the grasspea seed chain, there is a critical need to map out and initiate on how to advance its promotion. If one computes a 75% seed supply in grasspea, it would be about 110000 quintals of seed, at rate 1Q/ha. This could create agri-business opportunity, like is developing with other legumes.

On the other hand, there is a need to develop strategy on how to promote grasspea through its seed system development, because of its outcrossing nature of the crop which reaches 26%. This would also demand for the systematically designing technology development research approach. In sum, there is an inter-dependability of approaches, outputs and applications in the research and development pathways of the crop.

4.3A crop of choice for vagaries of climate shock

Grass pea fixes atmospheric nitrogen through rhizobial symbiosis, reducing the fossil fuel usage of the production and application of nitrogen fertiliser. The crop is often cultivated in rice paddies in Asian countries using a zero tillage approach, which reduces soil carbon loss. By allowing marginal areas affected by drought to become productive using grass pea, humid high biodiversity areas can be protected, also reducing carbon emissions from the decomposition of standing biomass and soil carbon Development of high yielding grass pea varieties also has the potential for reducing emissions of the greenhouse gas methane by displacing rice cultivation from some of the marginal areas where rice yields are limited by adverse soil conditions and nutrient availability. Additionally, the emission of nitrous oxide, another potent greenhouse gas, could be reduced by replacing artificial fertilisers with biological nitrogen fixation through crop rotations that include grass pea. Grass pea has also been shown to have potential in the bioremediation of heavy metals such as arsenic, cadmium, copper were reported including Brunets et al (2008) report of and lead.

Climate change often does not follow a predictable path. Ethiopia and others in the eastern Africa, is often facing climatic turmoil's ending up in catastrophic humanitarian crises. Rainfall pattern, distribution of rainfall including the onset and offset, and other associated phenomena affect crop yields. Grass pea is known to be adaptable to climate change and to have a big shock absorption capacity as it thrives under extremes of water stress, flooding (Campbell, 1977; Lambein et al., 1990; Haque, 1997; Fikre, 2008) and heat stress. Its adaptation to contaminated soil can even be exploited for phytoremediation of pollutants such as the accumulation of lead (Brunet et al., 2008). Small-scale farmers and pastoralists in Ethiopia are likely to bear the brunt of the negative impacts of climate change. Climate change may further increase poverty, water scarcity, food insecurity, etc.

The present scenario predicts an increase in temperature by about ±1.9 ^{0}C in four decades to come. Ethiopian farmers have survived a history of environmental calamities that made them risk averters by using crop diversification or cultivating crops that are tolerant to such calamities. Some non-conventional crops are known to better survive environmental disasters. Though officially banned, grass pea is produced in India and Nepal, even in some European countries there is growing interest in this ecologically friendly crop.

As Ethiopia is already moisture deficient, grasspea would be one of the most agro fit crops with important potential future (Figure 4). Possibly grasspea stands vagaries of climate heat and drought.

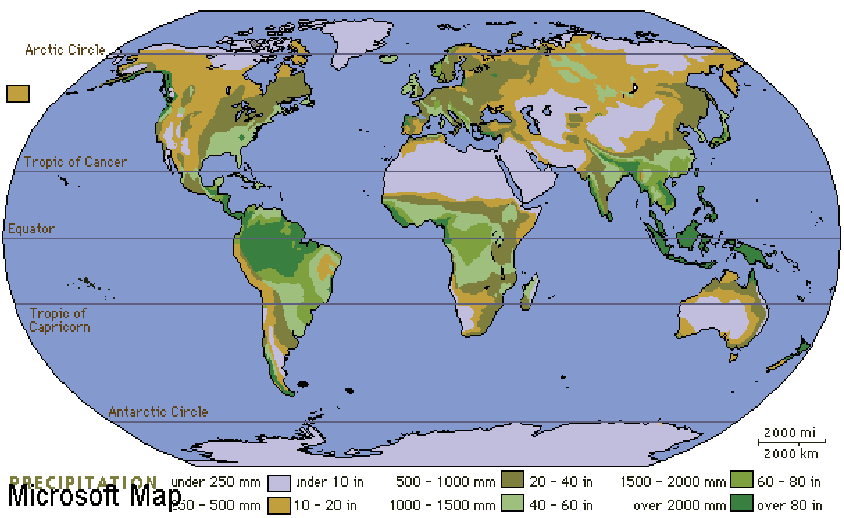

Figure 4: Global rain fall pattern

5. Gaps and opportunities with grass pea production, research and consumption

5.1 Suitability and adaptation

The unique nature of grass pea in Ethiopia is its productivity on marginal plots with low or no input. Under such conditions it is the most healthy and productive crop. Nonetheless, with changing environment this robustness may not continue forever. With the increase in production area, climatic dynamics and other factors, now there appear indications of vulnerability to a variety of pests. Epidemics of foliar fungal disease (own observation) and faba bean necrotic yellow nanovirus (FBNYV) (Adane and Alemu, 2010) have been reported recently. As high as 25% incidence was observed and the causal agent was by mechanical inoculation but was readily transmitted by aphids *Acyrthosiphon pisum* and *Aphis craccivora* from infected grasspea to healthy grass pea, faba bean, lentil, field pea and cowpea under greenhouse conditions. This was the first report of a virus naturally infecting cultivated grasspea in Ethiopia and elsewhere that coincided with heavy colonization of most grass pea fields with the pea aphid (*Acyrthosiphon pisum*).

5.2 Building the right perception and utilization

At large the public perception about neurolathyrism is based on traditional tales rather than scientific evidence. Many misconceptions prevail such as the link between neurolathyrism and the odor from flowering field and crucial information is lacking. This needs further socio-political action. It is equally important to introduce molecular techniques to alleviate toxicity and improve the nutritional quality in addition to the conventional breeding approach.

Based on the findings about the crop use values and risk factors, now it is possible to build the right communication and utilization of the crop. As there is continuous production and utilization of te crop, the smart way out for policy direction would be how best and safe can the crop be used, so that its undesired effects be minimized and utilization be enhanced.

There are pertinent opportunities with regard to research and development: i) Increasing the economic importance of the crop to enhance research opportunities, ii) Mobilization of the media and updating of already developed information in the public, iii) Identifying all recent and ongoing research projects on grass pea, iv) Research on the positive aspects of grasspea as a crop and as a phyto-ceutical need to be promoted.

5.3 Scoping the crop beyond

Sharing communality of challenges with in the era of climatic changes, grasspea should be seen as crop of mitigation in subtropical latitudes. As the two challenge ends; drought and excess water stresses are common phenomenon of today, crops with elastic genetic responses is critical. Grasspea is naturally evolved survived through hardships of climatic and environmental extremes. In so much as natural selection in favor of adaptive genetic components, grasspea could be seen as choice of the food and feed crop. Hence, grasspea can possible be expanding to other parts of the region or the continent.

5.4 Rationale in the new science frontier approach

Resource matters for scientific advances and priority affects what can happen when. Earlier biotechnological approaches on grasspea improvement have been very specific and with limited impact. The recent understanding of using the tool seems feasible as technical advances have extensively being expanded As grasspea offers outstanding potential for reducing energy inputs in farming, it stands strategic to feed big mass. The plant provides food as a grain crop and leafy vegetable, and is used as feed for livestock and as a green manure. Despite its overwhelming potential advantages, grass pea remains an underutilised crop grown mostly by poor and marginal farmers. This is chiefly due to the presence of β-N-oxalyl-l-α,β-diaminopropionic acid (β-ODAP), a neurotoxin present in low amounts in the seeds and vegetative tissues of the plant. The toxin is believed to cause lathyrism, a paralysis of the lower limbs in humans, usually occurring in epidemics in people subsisting on a near- exclusive diet of grass pea over 2-3 months. The genetics of β-ODAP biosynthesis remains poorly understood and the toxin levels in “low-toxin” lines developed by conventional breeding are unstable and often elevated under stressful cultivation conditions. This has led to bans on its commerce and utilization in the food industry in various countries. This has limited the interest from researchers and breeders in developing grass pea, making it a double-orphan crop.

There is big wish of technologists to utilize a genomics route to improve grasspea and make it a safe, priority crop for world food security. The genome data will be of tremendous value in identifying genes and regulatory sequences of the β-ODAP biosynthesis pathway, as well as identifying traits of agronomic importance, e.g. abiotic stress (e.g. drought, flooding, heat and poor nutrient availability) as well as biotic stress (diseases and insects) tolerance in grasspea. These data would be applicable to the improvement of other legume crops of global agricultural importance in order to make them resilient to climate change.

Sequence Utilization of grasspea could make an important contribution to food security and sustainability of global agriculture, but two obstacles currently hinder its widespread utilization: The presence of the neurotoxin β-ODAP and the lack of genomic and genetic resources for the species. The first has kept farmers from putting the yield stability of grass pea to use more widely, while the second has stifled research to remove the toxin and improve other agronomic traits.

Attempts to produce a toxin-free variety using large-scale mutant screen to identify low-toxin mutants and performing the crosses necessary to develop an entirely toxin-free variety. This approach has the added benefit over a GM approach in that improved varieties can be rapidly transferred to the farmer without regulatory hurdles.

In addition, a reverse genetics (TILLING) platform to permit rapid screening for both phenotypes and mutation discovery with a transcriptome based sequencing of RNA can be used in synergy with the genomic data to enhance the usability of each resource.

The genome data could be of significant value in identifying sequences for TILLING the genes in the β-ODAP biosynthesis pathway, as well as identifying traits of agronomic importance. This includes the genetic basis for abiotic (e.g. drought, flooding, heat and poor nutrient availability) as well as biotic (diseases and insects) stress tolerance in grass pea, and would be applicable to other legume crops (soybean, pea, lentil, faba bean etc.) of global agricultural importance with respect to climate change.

Conversely, the substantial breeding experience and knowledge of the genetics of those species could be applied to reproduce the agronomic improvements that have occurred over hundreds of years of pre-genome era domestication, in grasspea in just a fraction of the time. With the removal of the neurotoxin β-ODAP from the grasspea, we expect a surge of interest in the crop from scientists studying the responses of grasspea to abiotic stress and from breeders trying to improve agricultural traits of grass pea.

The genome data would also provide insights into comparative genomics across legumes and help in the development of high quality genetic and physical maps for marker-assisted and genomic selection strategies, as well as enable a genome editing platform for the grasspea.

The genomic data will provide molecular markers for conventional breeding, and enable the development of high quality genetic and physical maps, as well as the rapid identification of favourable genes using the TILLING platform being developed by our group. It is also important for all genome data tol be made freely available to the global grasspea research community to enhance the community to devise additional uses for this dataset.

6. Future directions

A simple fix of the β-ODAP biosynthesis pathway in grasspea, convert the hardy crop from just less priority of today to high value crop of the globe. Climatic changes seem to be opportunistic factors to consider grasspea as panacea. Science advance in resolving standing challenge of grasspea is crucial. On the other hand, still to suit a safe utilization procedure of the crop is an avenue of use value maximization. Grasspea is not restrictive in adaptation, and so many geographies of Africa and the rest of the world can host the crop. The natural hardiness of the crop to multiple environmental constraints, is an advantage for the scientific community to learn and mimic on outstanding genetics development. There has to reasonable resource allocation for the immediate future crop of high value.

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