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Contribution of White Lupin (*Lupinus albus* L.) for Food Security in North-Western Ethiopia: A Review

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Abstract: White lupin is a traditional crop mostly produced and consumed by smallholder farmers and is targeted for its grain and soil fertility maintenance values in Ethiopia. The objective of the present study was to review the biology, social and economic importance of white lupin and generate comprehensive technical information for different scholars who wish to study the crop in detail. White lupin can be used as source of protein for production of protein concentrates, for pharmaceutical purposes, due to the high alkaloid content as a natural component of plant pesticides and ectoparasite control, nitrogen fixation and crop rotation, livestock feed and pasture improvement, ornamentation, erosion control and soil stabilization, for fixing atmospheric nitrogen to soil, as a green manure contributing to improved soil structure, traditional alcohol production and hypertension treatment, live fencing and remediating polluted soils. Having these and other multiple uses, white lupin can contribute to sustainable livelihoods through household food security as it can widen the feed and food basket.

Key words: Food security, white lupin, protein, nitrogen fixation, alkaloid, soil fertility

INTRODUCTION

Ethiopia is an agrarian country where the majority of the people engaged in subsistence level crop production and rearing of livestock (Nigussie *et al*., 2012; Yisehak *et al*., 2011; Engedaw, 2012) and deriving almost half of the GDP from this sector (Engedaw, 2012). Most rural communities in the country depend on a limited number of field crops as their major source of food. Different studies have shown that rural communities face food insecurity and are chronically malnourished (Tefera, 2009) in protein and energy (Bhat and Karim, 2009; Habtie *et al*., 2009). According to UNDP (2006) report, more than half of the Ethiopian population, of whom the majority reside in rural areas (more than 83% of the population according to 2007 census result), is food insecure in relation to the recommended daily intake of 2,100 kilocalories per person per day (UNDP, 2006 cited in Tilahun (2010); Nigussie and Bogale, 2010).

The use of artificial nitrogen fertilizer has contributed enormously to the productivity of the 20th Century agriculture but has also been linked to environmental pollution and it is likely to become increasingly expensive due to the energy intensity of its production. Increasing prices of nitrogen fertilizer means an expanded role for grain legumes as alternative sources of biological nitrogen (Sweetingham and Kingwell, 2008) which lupin is the main candidate in this respect.

There are many plant species with significant feed, food, soil fertility maintenance (Yeheyis *et al*., 2010) and industrial potential which remain underutilized. According to Bhat and Karim (2009), the vast numbers of those underutilized species represent an enormous untouched commodity resource which can help to meet the increasing demand for food and nutrition, energy, medicines and industrial needs. Among those underutilized crops in Ethiopia, according to Engedaw (2012), lupin is the most important traditional crop mostly produced and consumed by smallholder farmers in the North-Western part of the country. As reported by the same author lupin production by the smallholder farmers is targeted for its grain and soil fertility maintenance values. The crop has advantages over more favored legume species in terms of nutritional value and tolerance to adverse climatic conditions (Small, 2012). Keeping this in view, the present study focuses mainly on reviewing the biology and uses of white lupin.

BOTANICAL DESCRIPTION AND ECOLOGICAL DISTRIBUTION

Lupin belongs to genus *Lupinus*, subfamily Papilionaceae and family Leguminosae (also called Genisteae or Fabaceae), the third largest family (EFSA, 2005). It is a cool-season (Bhardwaj *et al*., 2010; Uzun *et al*., 2007) legume which includes over 450 species

worldwide (EFSA, 2005) but only the following four major cultivated species have gained agricultural importance viz., white lupin (*Lupinus albus* L.), blue lupin (*L. angustifolius* L.), yellow lupin (*L. luteus* L.) of the "Old World" or Mediterranean area lupin species and one "New World" species namely Andean lupin (*L. mutabilis* L.), both wild forms and crops (Gladstones, 1998; Erbas *et al*., 2005). The last one is grown on a limited basis because of its hard seed and high alkaloid content (Bhardwaj *et al*., 2010; Gladstones, 1998; Kettel *et al*., 2003). *Lupinus* is a genus of self-or cross-pollinating, mostly indeterminate plant species native to diverse geographic regions (Payne *et al*., 2004). It has been cultivated as a grain crop for over 3,000 years, primarily in the Mediterranean, Australia, North Africa, parts of the Middle East and North and South America (Kwak *et al*., 2000; Kettel *et al*., 2003).

Originally the name of the genus descends from the Latin word '*Lupus*' meaning 'wolf.' The Romans believed that lupin robbed the soil of nutrients in the same way that a wolf would 'steal' domestic animals but the opposite is true as they are among legumes (Yorgancilar *et al*., 2009; Small, 2012; Engedaw, 2012). Lupin is known by different vernacular names such as 'Gibto' in Ethiopia (Tizazu and Emire, 2010; Habtie *et al*., 2009), the ancient Greeks referred to call lupin as '*Thermes*' while it is called '*Turmus*' in most Arab countries and India and the plant is named 'Termiye' or 'Acibakla' in Turkey (Yorgancilar *et al*., 2009). The local community in North-Western Ethiopia gives the name 'Gibto' because they thought the seed is originated and introduced from Egypt ('Gibtse' in Amharic). So, they name the crop after 'Gibtse' ('Gibt') (Getachew, 2009; Habtie *et al*., 2009).

White lupin agronomy: Lupins are adapted to well drained, light to medium textured soil and it is sensitive to soil pH, preferring acid to near-neutral conditions (pH of 4.5 to 7.5) (Huyghe, 1997; Jansen, 2006; Yeheyis *et al*., 2010). Lupins tolerate slightly alkaline soils (to pH 8.0), provided that the free lime or calcium content of the soil is low (the accepted maximum soil level of $CaCO_3$ is 3-5 g/100 g) (Jansen, 2006). In Ethiopia according to Gebreselassie (2002) the soil types in most traditional lupin growing areas are Nitosol and Acrisol with soil pH ranging between 4 and 5. Engedaw (2012) in his study reported that the smallholder farmers in the North-Western part of Ethiopia grow the crop with minimal agronomic practice, that is they plant the crop using zero-tillage or plowing their land only once and they didn't use any type of fertilizer and weed management technique.

The lupin seed is produced in pods which develop on the main stem of the plant. Pods contain between three and seven seeds and these seeds vary in size, color, appearance and composition depending on the species of lupin. Among them the seeds of *Lupinus albus* are the largest. They have a circular flattened shape and are cream in colour (Getachew, 2009). The life cycle of lupins can be divided into three stages: vegetative phase, floral phase and pod and seed growth phase. The rate at which the plant progresses through each phase depends on temperature and day length. Lupin can produce as many as 70 flowers on the main stem. The flowers open in ascending order, usually one or two per day. After fertilization, the flower ovary develops into a pod, or the flower dies and drops off. Flower abortion on the main stem is dramatic 80-90% and it is intensified by moisture stress, low temperatures (below 50°F) and high temperatures (above 80°F) at flowering. The ideal temperature for lupin growth is around 68 to 77°F during the day and 50 to 60°F at night (Kettel *et al.,* 2003) and according to Jansen (2006) a rainfall of 400-1000 mm during the growing period is optimal for yield.

In 14 to 20 weeks, flowering ceases and maximum dry matter is reached. All of the plant's nutrients are redirected from growth to seed filling. The crop is physiologically mature when the moisture content of the seeds falls to about 40%. At this stage, stems and leaves are light green to yellow, leaf drop starts and the cotyledons of the seeds are green. The rest of the crop season is primarily a drying process (Kettel *et al.,* 2003).

Origin and geographic distribution of white lupin: Lupins are considered to be polyploid in origin and are found in both the New and Old Worlds (Phan *et al*., 2007). *Lupinus albus* L. (White lupin) originates from South-Eastern Europe and Western Asia where wild types still occur. *Albus* in the scientific name *Lupinus albus* is Latin for white (Small, 2012). It is known to have been cultivated since ancient times in Greece, Italy, Egypt and Cyprus. The importance of white lupin has fluctuated often during the history of its cultivation; at present it has almost disappeared in central Europe while it is becoming more widely grown in the Americas. Today it is a traditional minor pulse crop, grown around the Mediterranean and the Black Sea and in the Nile valley, extending to Sudan and Ethiopia. It is also occasionally grown elsewhere, e.g., in Kenya, Tanzania, Zimbabwe, South Africa, Mauritius, United States and South America (mainly Brazil and Chile) (Jansen, 2006).

White lupin in Ethiopia: White lupin is a traditional crop in Ethiopia which grows at 1500-3000 m altitude. It is grown in the North-Western part of the country

(Francis, 1999) by smallholder farmers in the Amhara and Benishangul Gumuz Regions (Engedaw, 2012). According to Yeheyis *et al.* (2010) the local white lupin in Ethiopia is a very important traditional multipurpose crop and is grown in mixed crop livestock farming systems. The same authors reported that under traditional management systems the average grain yield potential of the crop was 1.2 t/ha and according to ECSA (2012) a total of 443,705.05 quintal white lupin is produced in Ethiopia in 2011/12. However, the use of the crop as human food and as livestock feed is limited due to its bitter taste attributed to its relatively high alkaloid content (1.43%) (Yeheyis *et al.*, 2011). In Ethiopia two types of cultivated lupin plants are found: a large-seeded type as grown in Egypt and Sudan but also a small-seeded type with small leaves (Jansen, 2006).

USES OF LUPIN

Lupin is a multi-purpose legume crop with a diverse spectrum of uses:

Forage for livestock: Lupins are one of several plant protein resources that have been witnessed to provide sound nutritional value to a range of aquaculture species, pig, dairy and beef cattle, sheep, goat, poultry, etc. It is also an important crop for organic livestock farms by playing the role of soybean meal (Yeheyis *et al.*, 2011).

Supplementary role: *Lupinus albus* flour is added for nutritive value and provides functional properties in bakery, cake, pastry, noodles, pickles, lupin-coffee, crisps, milk and yogurt analogues, pasta, emulsified meat and a variety of other food products to improve their nutritional value, aroma and texture of the end products (Getachew, 2009; Tizazu and Emire, 2010; Erbas, 2010). In Ethiopia it is consumed as a snack and lupin powder for preparation of stew/sauce ('shiro') (Habtie *et al.*, 2009) like other common legumes such as pea, bean, etc.

Ectoparasite control: In North-Western Ethiopia farmers use the leaves of lupin to wash livestock body as mechanism of controlling ectoparasites like ticks. In addition, a decoction of *Lupinus albus* is used as a wash to treat dermatitis in cattle (Leporatti and Impieri, 2007).

Phytoremediation use: Lupin plants can be used to remediate polluted soils by mechanisms of phytoremediation and phytoextraction, including phytostabilization and revegetation (Vazquez, 2006).

Traditional alcohol production: Lupin seed is used to prepare local alcoholic drink 'katikala' or 'gibto areke' especially in the North-Western part of Ethiopia (Tizazu and Emire, 2010). 'Gibto areke' is obtained by distilling a fermented brew prepared in the same way with other cereal-based alcoholic beverages, except that in this case seeds of *Lupinus albus* are used as one of the substrates (Ambaye *et al.*, 2002).

Traditional hypertension treatment: The local community in North-Western Ethiopia used '*gibto areke*' as a locally made antihypertensive medicinal preparation. In addition, to heal the same problem they use small quantity of lupin seed and fruit pounded with water, filtered; and the resultant juice is given orally in the morning for one month in Ethiopia (Ragunathan and Solomon, 2009).

Pharmaceutical use: Lupin containing alkaloids such as sparteine and anagraine has an important place in pharmaceutical industry (Yildiz, 2011) and cosmetics products or lotion producing firms (Kitessa, 1992).

Green manure: Lupin has high above ground biomass (Engedaw, 2012) and deep taproots (often going down to 2 m (Small, 2012)) which make it highly useful in aerating soil, or supplying it with oxygen and water. It helps create a better environment for growth and survival of other plants. This makes it excellent to be used as green manures.

Nitrogen fixation: Like other legumes, lupins obtain their nitrogen requirement through symbiotic association with N-fixing *rhizobium*. Annual nitrogen fixation or assimilation by *Lupinus* species is estimated to range from 145 to 208 kg N/ha/year and as reported by Jansen (2006) an atmospheric nitrogen fixation rates up to 400 kg N/ha/year have been observed in Europe and Australia. The high nitrogen yield of lupins can be exploited by using them in rotation with grasses or cereal crops. Therefore, lupins play a complementary or alternative role as sources of organic fertilizer to replenish nitrogen depleted soils in farming systems.

Ornamentation: Lupin has ornamental aesthetic values (Uzun *et al.*, 2007) to the environment having different color spikes of flower and it can serve as a cut flower in flowering period (Erbas *et al.*, 2005).

Erosion control and soil stabilization: Since lupin has a high tendency of growing on marginal lands, it will help to balance the ecology, thus could contribute in protecting the degradation of the environment and also helps in stabilizing soil (Uzun *et al.*, 2007).

Pest control: Lupin can be mixed in the soil during the flowering period in green houses to control some pests due to its alkaloids (Uzun *et al*., 2007). Yildiz (2011) as cited in Yorgancilar *et al*. (2009) suggested that waste of boiled lupin water which contain bitter alkaloid compound might be used in organic farming against the pests. Moreover, lupin extract has suppressive effect on plant parasitic nematode.

Rotation crop: Lupin is used as a rotational crop with cereals to explore its effect on sustained increment in yield and plant parasitic nematode population reduction (Yildiz, 2011).

Fencing: In North-Western Ethiopia one of the common uses of lupin is to use it as a live-fence by sowing it around other crops to protect the crops from livestock.

NUTRITIONAL PROFILE OF WHITE LUPIN SEEDS

The protein content of white lupin can be twice that found in other legumes which are commonly consumed by humans. There are variations in the protein content between species and cultivars as a result of the characteristics of the growing conditions and soil types ranging from 28-48% (Kohajdova *et al*., 2011), or according to Alamanou and Doxastakis (1995) the concentration may range 340-430 g kg^{-1}. Physicochemical study undertaken in Ethiopia on lupin by Tizazu and Emire (2010) witnessed 37 and 43% protein composition for samples procured from Debre Tabor and Dembecha, respectively. This protein content is comparable to soybean which possesses about 40% protein (Xu *et al*., 2008) and as for all legumes, lupin bean protein is rich in lysine, leucine and threonine; and deficient in sulfur-containing amino acids (Joray *et al*., 2007; EFSA, 2005).

Dietary fiber represents 40% of the kernel weight of white lupin which is a higher level than in most other legumes. The seed cover of *Lupinus albus* contains after the debittering process 89% of insoluble dietary fiber. The main component of the insoluble dietary fiber is cellulose (79%). Other ones, i.e., hemicelluloses and lignin, remain at the levels of 14 and 7%, respectively (Kohajdova *et al*., 2011). As invoked in Erbas (2010) lupin can contain more than 150 g kg^{-1} of lipid and dietary fiber.

Although lupin belongs to the legumes and is not described as an oilseed crop, it has a considerable amount of oil in its seeds (Uzun *et al*., 2007). As reported by Kohajdova *et al*. (2011) it contains approximately 5-20% of crude oil in the whole seed. In general, lupin oil is characterized by a balanced fatty acid composition with total saturated fatty acids of 10% and total unsaturated fatty acids of 90%.

Lupin seed contains minute amounts of starch (5-12%) while other common legumes contain up to 50% starch (Mohamed and Rayas-Duarte, 1995). According to Feldheim (1999) commercial lupin contains on average 3-5% of minerals with higher content of calcium and phosphorus; and Solomon (2007) reported 2.9-4.3% ash and 11.9-13.6% crude fat.

According to Jansen (2006) nutritional analysis of raw mature *Lupinus albus* seeds contain per 100 g edible portion: water 10.4 g, energy 1552 kJ (371 kcal), protein 36.2 g, fat 9.7 g, carbohydrate 40.4 g, Ca 176 mg, Mg 198 mg, P 440 mg, Fe 4.4 mg, Zn 4.8 mg and vitamin A, B and C.

Anti-nutritional activity in lupin: The major anti-nutritional factors in lupin are quinolizidine alkaloids which are responsible for the bitter taste in lupin and human and animal toxicity because they act as neurotoxins. Alkaloids are nitrogen-containing, water-soluble compounds produced in the chloroplasts (Olver, 1998) and they are responsible for the bitter taste, lower palatability and toxicity in lupin seed and forage. In bitter cultivars, the alkaloid contents range between 0.5 and 6% and in sweet cultivars it is less than 0.02% (Yeheyis *et al*., 2012). The major alkaloids present in seeds of *Lupinus albus* are Lupanine (Huyghe, 1997; Olver, 1998; Getachew, 2009), hydroxyaphylline, albine, multiflorine (Getachew, 2009), anagraine (Yildiz, 2011) and sparteine (Huyghe, 1997; Erbas *et al*., 2005). General toxic symptoms caused by quinolizidine may include malaise, nausea, respiratory arrest, visual disturbances, ataxia, liver damage, progressive weakness and coma (Getachew, 2009; Erbas *et al*., 2005). In livestock it causes neurological paralysis, reduced fertility in females and birth abnormalities (Habtie *et al*., 2009; Small, 2012).

Lupin seeds are consumed in Ethiopia as snack by roasting followed by soaking in running water to remove the alkaloids which are responsible for the bitter taste (Solomon, 2007), for 4-9 days and washing it twice (Yeheyis *et al*., 2011).

Diseases: The most common and known lupin diseases are bean yellow mosaic, anthracnose, brown leaf spot and fusarium wilt (Engedaw, 2012). Of these anthracnose remains the most important disease threat (Sweetingham and Kingwell, 2008). According to Yeheyis *et al*. (2010) white lupin produced in Ethiopia is resistant to lupin anthracnose disease which currently is a problem for the cultivation of white lupin in some parts of Western Australia and Europe. This disease is caused

by a fungus known as *Colletotrichum gloeosporioides* (Engedaw, 2012). It is mainly a seed-borne disease which means that the disease is present in the crops very early in the cycle. Symptoms include cankers on the stems which curl and break (Huyghe, 1997).

CONCLUSION

Food security in rural communities can be improved by diversifying the existing farming systems. For this white lupin can play an important role due to its multipurpose functions. The ethno-botanical and medicinal uses of this traditional multi-purpose crop need to be explored in Ethiopia for better utilization.

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