



## **REVIEW ARTICLE: AN OVERVIEW ON BIOLOGY AND ECOLOGY OF LUPINUS ALBUS L.**

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### **REVIEW ARTICLE**

#### **ABSTRACT:**

Lupinus albus L. is usually cultivated for its edible seeds. In Egypt it is frequent an escape from cultivation in Nile Delta and Oases of the Libyan Desert. Lupin has a tap root system, the main root reaches depth of 1-2 m which bears nodules formed by Bradyrhizobium for nitrogen fixation. Lupinus albus adapts to phosphorus (P) deficiency with a highly coordinated modification of root development and biochemistry resulting in short, densely clustered secondary roots called proteoid or cluster that release vast amounts of phosphate-mobilizing carboxylates capable of making poorly available nutrients more available.. It has the ability of accessing sparingly available P, as well as being able to symbiotically fixation of N<sub>2</sub>, thus it would provide Lupinus species possess ideal combination of traits to act as ecosystem engineers. This plant was important to many Mediterranean civilizations and was domesticated in the old world and new world. It is known to have been cultivated since ancient times in Greece, Italy, Egypt and Cyprus. It has unique traits of protein, low starch, and contains alkaloids that provide the plant a chemical defense against herbivores. It adapts best in well-drained, mildly acid or neutral soils of light to medium texture.

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#### **INTRODUCTION:**

Lupinus albus L., commonly known as the white lupin or field lupine, is a member of the genus Lupinus (family Fabaceae). Lupinus albus L. did not record in the Egyptian flora since Täckholm (1956) while Täckholm (1974) recorded it as a cultivated plant for its edible seeds and frequent as an escape from cultivation in Nile Delta and Oases of the Libyan Desert. Also, it was recorded in Boulos (1995), El-Hadidi and Fayed (1995) and Boulos (2009).

Shaltout et al. (2010) recorded it in the abandoned fields as well as in the fields of winter crops, and evaluated as a very common in Nile Region and Oases of the Western Desert. In the Egyptian flora (Boulos199: Lupinus digitatus Forssk. is endemic to Egypt and L. angustifolius L. which inhabit the edges of fields , Lupinus palaestinus Boiss. Is near-endimic to Sanai and Palestine, L. albus L. is cultivated and also occurs as a causal or escape from

cultivation (Shaltout 2014). Its vernacular name is *termis*, of which two cultivars: Giza 1 cultivated in north Egypt and Giza 2 cultivated in south Egypt.

The review reports on the current knowledge about biology and ecology of *Lupinus albus* L.

### TAXONOMY :

*Lupinus albus* L. (Fabaceae), have the following synonyms: *Lupinus sativus*

Gaertn. and *Lupinus termis* Forssk  
Common names are bitter white lupin, broad-leaved lupin, broadleaf lupin, Egyptian lupin, European white lupin, Mediterranean white lupin, white lupin and white lupine (Lim 2012). There are many vernacular names in many languages (Table 1).

Table (1) Vernacular names of *Lupinus albus* L. (Lim 2012).

Country	Common name
Arabic world	Bâqilâ Shâmî and Turmus
China	Bai Hua Yu Shan Dou and Bai Yu Shan Dou
Denmark	Lupina Bílá and Vlčí Bob Bílý Czech
Holland	hvid bitterlupin and hvid lupin; bittere lupine, lupine, lupine sort and witte lupine
Estonia	valge lupiin
Ethiopia	gibto and finnish Valkolupiini
France	lupin blanc, lupin llanc amer, lupin d'egypte
Germany	ägyptische lupin, weisse lupine, weiße lupine, weiße bitterlupine and wolfsbohne;
Israel	turmus lavan
Italy	lupino bianco, lupino bianco amaro and lupino egiziano
Japan	shiro bana ruupin
Korea	paek saek ru p'in
Norway	hvit lupin polish and lubin biały;
Portugal	tremeceiro branco and tremeço branco amargo
Romania	lupin alb,
Russia	ljupin belyj
Spain	altramuz, alttramuz blanco, altramuz blanco amargo and tramuso
Sweden	vitlupin;
Turkey	aci bakla, ak aci bakla, misir baklasi and yahudi bakla

### PLANT MORPHOLOGY:

*Lupinus albus* L. is an annual, erect, branched, bushy, short-hairy herb with a strong taproot. Leaves are alternate and compound with 5-9 leaflets, nearly smooth above and hairy beneath. Individual plants produce several orders of inflorescences and branches, resulting in clusters of long, oblong pods, each cluster having 3-7 pods, and each pod containing 3-7 seeds (Jansen 2006; Lim 2012). Annual herb with white flowers in long terminal

racemes with leaves digitate with many leaflets, seeds of *L. albus* larger than in others and about 12-4 mm across. (Täckholm 1974).

### SEED CHARACTERISTICS:

Flowering time extends from February to April. Seed shape is slightly flattened, oval in shape, while seed color is light yellow, the hilum shape is groove, hilum elevation is sunken, and hilum position is basal. Seed texture is smooth, while seed outline is curved (Fig. 1).



Fig. (1). Fig. 1 Line drawing of *Lupinus albus* entire flowering plant with pod, after Philibert (2019). The quantitative characters of *Lupinus albus* seeds shows that the mean of the seed

length and width almost the same in the two varieties (Giza1 and Giza 2), while the mean of its seed weight varies from 36.7 to 37.6 mg seed -1, thickness ranged from

0.4 to 1.1 cm seed-1 (Table 2), Also the seed weight varied from 33.7 to 34.2 mg seed -1 in both varieties.

Table (2) seed characteristics of *Lupinus albus* varieties (Giza 1 and Giza 2); recent data estimated by the first author.

Character	Giza1				Giza2			
	Max.	Min.	M.	SD	Max.	Min.	M.	SD
Length (cm seed-1)	1.3	0.7	0.98	0.092	1.5	0.5	0.98	0.15
Width (cm seed-1)	1.2	0.6	0.98	0.11	1.9	0.1	0.98	0.19
Thickness (cm seed-1)	1.1	0.1	0.26	0.103	0.4	0.1	0.25	0.064
Weight (mg seed-1)	36.69	30.96	33.65	1.62	37.55	30.54	34.22	2.10

### PROTEOID ROOTS:

Lupin species with a tap root system, the main root reaches the depth of 1-2 metres. Lupin roots, especially the main axis, bear nodules formed by *Bradyrhizobium* for nitrogen fixation.

In addition, morphological adaptations occur in many plants for

increased nutrient uptake. Proteoid roots that also known as cluster roots, can form in response to phosphorus or iron deficiency (Gardner et al. 1982; White & Robson 1989; Gilbert et al. 2000; Lambers et al. 2006b). *Lupinus albus* L. adapts to phosphorus (P) deficiency with a highly coordinated

modification of root development and biochemistry resulting in short, densely clustered secondary roots called proteoid or cluster roots (Uhde-Stone et al. 2005). Cluster roots can be induced by phosphorus (P) or iron (Fe) deficiency (Zhibin et al. 2012).

Lupin has the most characterized response to P shortage by plant roots with its shape and structured development, which can be considered as an evolutionary response (Niu et al. 2013). Vigorous cluster root growth under low P availability in the soil of lupin have the ability of secreting phosphatase-sAPase, under conditions of low phosphorus which hydrolyze organic phosphate in the rhizosphere and providing inorganic phosphate to the plant (Wasaki et al. 2003). Formation of cluster roots is one of the most specific root adaptations to nutrient deficiency, controlled by both shoot and root P concentrations. Cluster root release mainly citrate, but also some malate; while the major organic acid released by root tips of both non-proteoid and proteoid roots was malate. (Chunjian & Ruixia 2005). The role of proteoid roots formation under P, Fe or K deficiencies were studied by Ruixia and Chunjian (2003) and found that root clusters formed when plants were grown under P and Fe, but not under K

deficit conditions; cluster roots releases citrate and some malate.

Nitrogen nutrition deficiency can influence cluster root formation in many wild species, but the effect of N form on cluster root formation and root exudation by white lupin is not known. Sas et al. (2002) found that  $\text{NH}_4\text{-N}$  nutrition stimulated cluster root formation and  $\text{H}^+$  extrusion by roots of P-deficient lupin Li et al. (2008) investigated the critical level of shoot phosphorus concentration for cluster-root formation in *Lupinus albus* and found that the localized phosphorus (P) supply affects cluster-root formation and citrate exudation; The formation of cluster roots is regulated by shoot P concentration with a critical level of 2-3 mg g<sup>-1</sup>, citrate exudation is predominantly governed by shoot P status, whereas proton release strongly responds to local P supply. Lin Shen et al. (2005) found a similar results when studying white lupin plants grown in nutrient solution, using a split-root system with two compartments to examine the effect of localized P supply on nutrient uptake, cluster root formation and root exudation that cluster root formation and citrate exudation are regulated by the shoot P and affected by localized supply of external P..



Fig. (2): *Lupinus albus* entire root with proteoid roots; photos taken by the first author.

Lupin produce cluster roots, which release vast amounts of phosphate-mobilizing carboxylates (inorganic anions) mainly citrate and protons that capable of making poorly available nutrients, in particular P, more available (Lambers et al. 2013).

#### **NITROGEN FIXATION:**

lupin are modulated legume capable of nitrogen fixation by nitrogen fixing *Bradyrhizobium* bacteria in its root nodules and increases the nitrogen level of the soil (Lim 2012). Therefore, they are tolerant to infertile soils and have long been incorporated in agricultural practice as green manure, and in rotation with other crops. In Australia, a modern farming system based on wheat:lupin rotation has been in place for over 40 years (DAFWA 2010). David et al. (2014) found that white lupine (*Lupinus albus* L.) fit to improve acid soils in south-western Romania and cultivation of wheat after white lupin increased of the yield with 26%. This means that white lupin ensures the most economically advantageous increase in yield. It is highly adapted to growth in a

low-P environment. Schulze et al. (2006) found that enhanced nodulation in cluster root zones and increased potential for organic acid production in root nodules appear to contribute to lupin's elasticity to P-deficiency.

#### **ORGIN AND GEOGRAPHICAL DISTRIBUTION:**

lupin crops were important to many Mediterranean civilizations and was domesticated in the Old and New World (Putnam 1993). It originates from south-eastern Europe and western Asia where wild types still occur (Lim 2012). It is known to have been cultivated since ancient times in Greece, Italy, Egypt and Cyprus (Nigussie 2012). It is mainly distributed around the Mediterranean (Gladstones, 1974 as quoted by Huyghe (1997) and along Nile Valley. In these areas, it has been traditionally cultivated for several thousand years. These cultivated populations constitute the genetic resources of the species and are all bitter materials with an indeterminate growth habit (Huyghe 1997).

Lupinus cultivated types are distinguished as subsp. albus (synonym: *Lupinus termis* Forssk.). The distribution area of lupin is in South Africa and Americas where mostly sweet low-alkaloid modern cultivars are grown, whereas in the Mediterranean region and eastern Africa bitter landraces prevail (Jansen 2006). The importance of 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. (Fig. 3) 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 (Nigussie 2012).



Fig. (3). Global distribution of *Lupinus albus* L. (grey color) in the World (prepared by the first author)

In Egypt, *Lupinus albus* is cultivated in nearly all the country (Fig. 4): Sharkia, Ismailia, Menoufia, Giza, Beni

Suef, Ismailia, Minea, Assiut, Suhag Qena and Aswan (Statistical information Ministry of cultivation in Egypt 2001-2014).

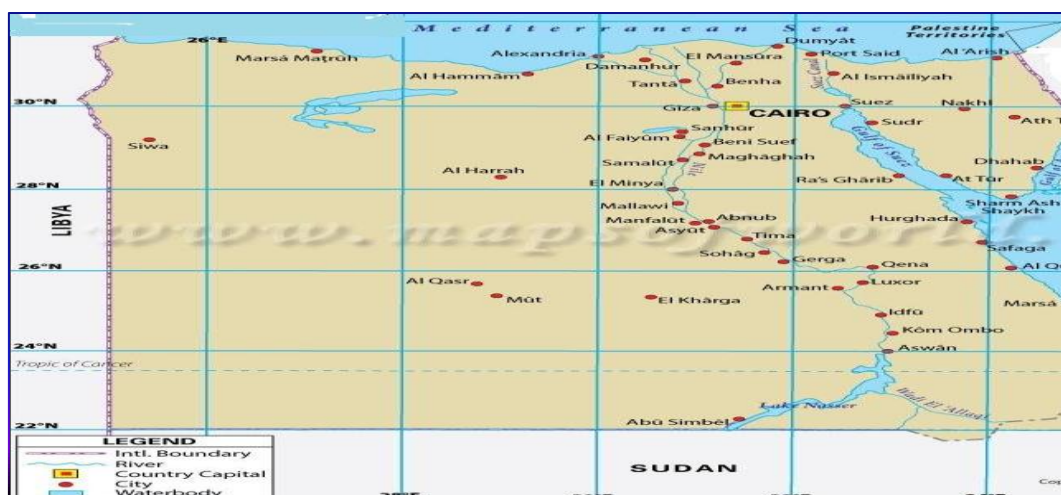


Fig. (4). Map showing *Lupinus* Cultivation In Egypt. Ismailia, Giza, Beni Suef, Minea, Assiut, Qena, Aswan.

## PHYTOCHEMISTRY:

Methanolic seed extract of *Lupinus albus* contains , reducing sugars, glycosides, , while no carboxylic acid, lipids of fatty acids present (Abdallah et al. 2017). Lupin seed storage protein is made up of 85% globulins and 15% albumins (Petterson 1998). Compared to other grain legumes such as peas, soybean and string bean, lupins appear to contain the least amount of proteins having anti-nutritious properties: inhibitors of proteinase and hemagglutinins (Kurlovich et al. 2002). Lupins are typically low in starch and most species contain less than 1.5% in the seeds. Therefore, the non-starch polysaccharides (NSP) constitute the major portion of the carbohydrate fraction of all lupin species, typically being about 40% (Glencross 2001). *Lupinus* contains alkaloids that it's main role is to provide the plant a chemical defense against herbivores (Wink 1992). Also, lupin has a unique traits of protein, fatty acids with a desirable ratio of omega-6 to omega-3 acids, and fibre as well as other specific components, the presence of oligosaccharides and antioxidants or non-starch carbohydrates,

make lupin an excellent component in many healthy diets (Prusinski 2017).

## HABITAT:

Lupin adapts best in well-drained, mildly acid or neutral soils of light to medium texture, with pH 4.5–7.5. Growth is hindered on heavy clays and waterlogged soils. Calcareous or alkaline soils cause chlorosis and reduce growth although some cultivars are more tolerant to soil salinity and heavy soils.(Lim 2012); In Egypt it is reported that *Lupinus albus* could tolerate pH 7.5- 9.4 (Christiansen et al. 1999; Kerley et al. 2002). High-yielding, high-pH-tolerant, frost-tolerant dwarf cultivars, well adapted to local ecological conditions. It appears that bitter cultivars tolerate cold and disease stress better than sweet ones (Jansen 2006).

In Egypt, The greatest area cultivated with lupin (7253 fed) was achieved in 2011 with a yield of 3.967 ton fed-1 and a total production of 6300 ton (Table 3). The minimum area cultivated with lupin (2390 fed) was obtained in 2013 with a yield of 3.549 ton fed-1 and a total production of 1760 ton (CLWR 2014).

Table (3) Area (fed), yield (ton fed-1) and production (ton) of lupin crop during 2000 to 2014.

year	Total			New Land			Old Land		
	Area (fed)	Yield (ton fed-1)	Prod. (ton)	Area (fed)	Yield (ton fed-1)	Prod. (ton)	Area (fed)	Yield (ton fed-1)	Prod. (ton)
2000	6354	0.671	4264	1960	0.397	778	4394	0.793	3486
2006	3417	0.815	2784	823	0.617	508	2594	0.877	2276
2007	3745	0.770	2885	1695	0.625	1060	2050	0.890	1825
2008	3098	0.770	2384	1524	0.730	1113	1574	0.807	1271
2009	7025	3.95	5735	4065	2.041	2738	2960	4.202	3024
2010	7126	3.923	6128	3429	2.21	2577	3697	4.163	3551
2011	7253	3.967	6300	4102	2.216	3246	3151	4.198	3054
2012	2603	3.78	3068	1379	3.133	1064	2224	4.241	2004
2013	2390	3.549	1760	1363	2.246	999	1054	3.499	761
2014	2570	3.468	1839	1796	1.416	1271	774	0.734	568

## USES:

1. In Italy, Greece, Spain, Portugal and some regions in Brazil, white lupin seeds are consumed as a popular snack (Lim 2012). lupin is considered to be a rich source of protein with a notable content of lysine and is being increasingly used in bakery, confectionery, snacks and pastry products due to its multifunctional properties (Guillamón *et al.* 2010).
2. In Ethiopia, lupin seeds are used as roasted bean (called kolo) and to prepare a local alcoholic drink called katikala and other food products especially in the north-western part of the country (Tizazu & Emire 2010; Zelalem & Chandravanshi 2014). Also it cultivated in Ethiopia and used as 'Shiro' flour for the people living in the north western part of Ethiopia. It is also used for maintaining soil fertility and as a food (Zelalem & Chandravanshi 2014).
3. The composition of the seed and especially the high protein content makes lupin highly suitable for livestock diets as a protein-rich product in intensive farming systems. The low level of antinutritional factors facilitates a direct on-farm use of white lupin in self-sustained systems.
4. Since it often can grow on land unsuitable for other crops (too saline, heavy, acid or poor), the development of cultivars adapted to tropical African conditions is highly recommended. (Jansen 2006).
5. Before 2000 BC., *L. albus* in ancient Greece and Egypt was used to produce seeds for human and animal consumption, as well as for cosmetics and medicine and during 1000-800 BC. It was also, used as green manure in ancient Rome and, in other Mediterranean countries (Kurlovich 2002; Clements *et al.* 2005). Nowadays, lupin used as a fodder and food crop, as well as an ornamental plant, and used as traditional food in the Mediterranean region and the Andean highland in South America (DAFWA 2010).
6. Seeds are used among others for the production of gluten-free flour, bacterial and fungal fermented products, noodle and pasta products, as substitutes of meat, egg protein and sausages. Also it is cooked, roasted and ground and mixed with cereal flour in the production of bread, crisps, pasta, crisps and dietary dishes (Prusinski 2017).
7. In traditional medicine, lupin is used for various disorders, for example its meal added with honey or vinegar is used as a treatment for worms, while infusions or poultices are applied for boils and skin complaints (Lim 2012). Lupin is also used as green manure crop, as forage and as livestock feed.
8. In southern Europe it is still a traditional green manure crop in vineyards and olive plantations. Lupin is a good honey plant and an attractive annual ornamental; its inflorescences are used in floral arrangements. Burning seeds are used as an insect repellent. (Lim 2012).



## **GENETIC RESOURCES AND BREEDING:**

Major germplasm collections of lupin are available in France (INRA, Station d'Amélioration des Plantes Fourragères, Lusignan, 1400 accessions), United Kingdom (University of Reading, Reading, 1100 accessions), Australia (Western Australian Department of Agriculture, South Perth, 890 accessions) and Spain (Servicio de Investigación y Desarrollo Tecnológico, Guadajira, 690 accessions). In tropical Africa, small collections are held in Ethiopia (International Livestock Research Institute, Addis Ababa, Ethiopia, 25 accessions) and Kenya (National Genebank of Kenya, Crop Plant Genetic Resources Centre, KARI, Kikuyu, 20 accessions) (Jansen 2006). Major objectives in breeding of white lupin are to produce rapid-growing, alkaloid-free, disease-resistant cultivars (particularly against anthracnose). The level of cross-pollination may limit the relevance of sweet white lupin cultivars in regions where also bitter weedy or cultivated types are present, because pollen of the latter would reintroduce the bitter character in farm-saved sowing seed. Sweet cultivars, however, are a prerequisite for any further breeding advancement. Commercial cultivars are pure lines bred through pedigree selection. Some well-known cultivars of white lupin are: Eldo, Kiev, Multolupa and Ultra. From Ethiopia Bahar Dar is known. (Jansen 2006; Wolko et al. 2011).

## **ASSOCIATED WEEDS:**

Unfortunately, there are no recent studies about the associated weeds with lupin cultivation. In Egypt, in general, the weeds of winter crops, particularly the sand soils dominate the lupin cultivation (Morsi & Abd-Elgwad 1965). Among the weeds that are expected to invade the lupin cultivation are: *Vicia sativa* L., *Sonchus oleraceus* L., *Rumex dentatus* L., *Urtica urens* L., *Melilotus indica* (L.) All., *Malva parviflora* L., *Lathyrus hirsutus* L., *Ammi majus* L., *Cichorium endivia* L., *Anagallis arvensis* L., *Beta vulgaris* L. and *Emex spinosus* (L.) Campd. (CLWR 2014).

## **DISEASES:**

Lupins are susceptible to a wide range of diseases. Although lupin diseases caused by bacterial pathogens (Lu & Gross 2010). The major diseases of lupin are root rot and brown leaf spot caused by *Pleiochaeta setosa*, anthracnose (*Colletotrichum acutatum*), resulting in early plant death through stem breakage, and rust (*Uromyces lupinicolus*). Sources of resistance to anthracnose have been found in Ethiopian landraces, but resistant cultivars are not yet available. Bean Yellow Mosaic Virus (BYMV) is the major virus disease; it is transmitted by seed. No sources of resistance have yet been identified. Lupin is immune to Cucumber Mosaic Virus (CMV), a major disease of other *Lupinus* spp. Pathogens that might affect Lupin are shown in Table (4).

In Ethiopia harvesting is in December. Seed yields are 500–4000 kg/ha (Jansen 2006). Anthracnose has been found in most lupin producing areas of Western Australia and South Australia, but it is most serious in the high rainfall zone of the northern agricultural region in Western Australia (Thomas 2003). The disease is not known to occur in lupin crops in New South Wales, Victoria or Tasmania (Davidson et

al. 2007). The fungal pathogen *P. setosa* is responsible for both brown leaf spot and Pleiochaeta root rot diseases of lupins. It has affected lupin production in all continents where lupins are cultivated and is the most widespread and damaging pathogen of lupins in Australia, particularly in Western Australia (Sweetingham 1997; Sweetingham et al. 1998).

**Table (4) Pest and pathogen cause that might affect *Lupinus albus* L.**

Pest	Pathogen Cause
Bean seedling maggot ( <i>Delia platura</i> )	seedlings to wilt and die
Beetle and moth larvae ( <i>Agriotes</i> and <i>Agrotis</i> spp.)	killing seedlings
Slugs	attacking leaves
Thrips ( <i>Frankliniella</i> spp.)	attacking flower buds and leaves
Mirid bugs	attacking young pods
Budworms <i>Helicoverpa armigera</i>	feeding on pod and seed

#### **ECOLOGICAL SIGNIFICANCE:**

Regular use of P fertilizers in agricultural system has raised the soil P status. This P is not readily available for plant growth, except for species like *Lupinus* which has a phosphorus–acquisition strategy (Lambers et al. 2013). Accessing sparingly available P, as well as being able to symbiotically fix N<sub>2</sub> would provide *Lupinus* species with an ideal combination of traits to act as ecosystem engineers (Lambers et al. 2013). The efficiency of acquisition of immobile nutrients such as P depends on root architecture, function (including root hairs and cluster roots), rhizosphere modification (carboxylate and proton exudation), rhizosphere organisms, symbiotic associations (mycorrhizal and rhizobial) (Lambers et al. 2006a).

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## بيولوجية وبيئة نبات الترمس *Lupinus albus* L.: رؤية مرجعية.

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### الملخص العربي :

يزرع نبات الترمس عادة لبذوره الصالحة للأكل، كما أنه كثيرا ما ينمو هاربا من الزراعة في دلتا النيل وواحات الصحراء الليبية. جذر نبات الترمس من النوع الوتدي ويصل طوله من 1 إلى 2 متر ، ويحمل العقد البكتيرية القادرة على تثبيت النيتروجين الجوي. يتكيف نبات الترمس جيدا مع نقص عنصر الفسفور عن طريق عمليتين متزامنتين : تحول الجذور لتصبح قصيره وكثيفه (تسمى الجذور البتروتيديه)، وكذلك إطلاق كثير من المواد الكريكسولييه من الجذر قادرة على تحويل العناصر الغير متاحة الى عناصر متاحة، وبالأخص عنصر الفسفور. وعمليتي تثبيت النيتروجين وإذابة الفسفور وتحويله لصورة متاحة بيولوجيا، من الصفات هي المثلتي تى جعلت هذا النبات يعمل كمهندس للنظام البيئي. كانت زراعته مهمه في حضارات البحر المتوسط، وكان معروفا في العالم القديم والجديد، ومن المعروف قدم زراعته في اليونان وايطاليا ومصر وقبرص. وبالنسبة لتركيبه الكيميائي يحتوى على بروتينات فريده، وذو محتوى منخفض من النشا، ويحتوى على القلويدات التي لها دور رئيسي في حمايته من الحيوانات الرعوية. يتكيف هذا النبات جيدا في التربة جيدة التهوية ذات الأس الهيدروجيني الحمضي أو المتعادل وذات القوام الخفيف أو المتوسط.