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EMERGING ROLES, BOTANICAL SIGNIFICANCE, PRODUCTION, CULTIVATION OF *CYAMOPSIS TETRAGONOLOBA* & ITS DERIVATIVES AND FUTURE PERSPECTIVES

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Abstract

Cyamopsis tetragonoloba is the most important crop that comes from the endosperm of the seed of the legume plant. Its leaves are alternate, trifoliate which are borne on long petioles, and stem is tall and slender. The color of guar seed ranged from black to dull white that seed coat pigments consisted of galactose, gallic acids, ferric ions and 2, 3, 4-trihydroxybenxoic acids. Its leaves can be consumed as spinach, and the pods are used as vegetables or salad. It has a wide range of applications because of its nutritive value. It is used an appropriate material in the drugs delivery due to its antioxidant properties. Guar is the good nutritious fodder source for cattle. It is used in meat goods to improve casing stuffing. Galactomannan is an effective source to control diabetes, cancer and obesity. Due to its lower antigenicity, it is used in the healing of wounds. Guar gum derivatives have the ability to stop the carcinogen-activator-enzyme, cytochrome-P450-1A (CYP1A), and also promote carcinogen-detoxification-enzymes glutathione S transferases (GSTs). The guar gum and its derivatives are extensively used for the control of blood sugar. Silver-nanocomposites from the guar gum is used for the detection of ammonia. This review highlights on emerging roles, botanical significance, production, cultivation and of guar and its derivatives.

Keywords
Guar Gum, Galactomannan, Shelf Life, Cancer, Obesity, Water Treatment

1. Introduction

Guar (*Cyamopsis tetragonoloba* L.) is one of the few crop species that have an ambiguous origin. Livestock contributes 60.54 % in agriculture and 11.22 % in GDP, recorded the growth at 4.0 % against the target of 3.8 %. It has been

speculated that guar develop from trans-domestication of drought tolerant African native *Cyamopsis senegalensis*, which was taken basically from Africa (Ahmed *et al.,* 2003). There might be possibility that guar was domesticated in Africa and Arabia then got its way to India, Pakistan and USA. These three states are the major producers, processors and exporters of today's guar gum. For guar cultivation, seed rate varies from 15-kilogram to 45-kilogram per hectare. Seed rate also depend upon spacing and soil moisture (Mathur and Mathur, 1981).

Due to antioxidant nature and the mucoadhesive properties of galactomannan gum make it an appropriate material in the drugs delivery applications as it forms solid case. Guar-gum shows solid interactions with mucus-lining of tissues, enhancing localization and interactions time at contact site. The guar gum and the derivatives of guar gum are extensively been used for the control of blood sugar (Bhujel *et al.,* 2018). Galactomannan and the derivatives play a vital role in the cancer therapy specially the colorectal cancer, the most common cancer form due to intestinal ailment. A silver-nanocomposite from the guar gum is manufactured for optical-sensor for the detection of ammonia. From an aqueous solution Cr (VI) is removed by using the guar gum nano-zinc-oxide bio-composite (GG/nZnO) as an absorbent (Brooker, 2005).

The guar gum is used as a stabilizer in gamma rays induced production of Ag-clusters in an aqueous medium. Guar is the good nutritious fodder source for cattle, but due to the presence of hydrocyanic acid in guar pods, only mature pods can be consumed. In several foods guar gum is used as stabilizer to change its fiber source or viscosity (Crossman, 2017). With starch, wheat and some other gums it shows viscosity synergism. It is used in ice-creams, in which it adds chewiness, and resistance to heat shocks. In medicinal industry it has a wide range of application. It is a hydro colloidal polysaccharide (Dewey, 1959).

This review summarizes emerging roles as drug delivery, for treatment of diabetes, cancer, guar gum-based hydrogels for water purification, chemical structure, botanical significance, production, cultivation. It has a wide range of applications because of its nutritive value. It is used an appropriate material in the drugs delivery applications due to its antioxidant properties. We have also highlighted the food and pharmaceutical applications of guar.

2. Chemical Composition of Guar Gum

The galactomannan is an uncharged naturally existing gum. The guar gum contains protein, phosphorus, water soluble polysaccharides, ash, water soluble fraction and the water insoluble fraction. Galactomannan or guar gum is the polysaccharide present in the seed endosperm of cluster bean (Dhami *et al.,* 2018). Galactomannan also called guaran, containing a straight chain unit of (1-4) B-D-manopyranosyl with (1-6) B-D-galactopyranosyl unit residues as side chain. This polymer having molecular weight of 220,000 Daltons is a relatively large polymer. The Guaran hydrated very quickly in cold water and give a thixotropic, highly viscous solution. A dispersion of 1.0 percent has viscosity of about 6000 cps, depending on the presence of food components, temperature and strength (Ghimire *et al.,* 2018).

Table 1: Shows the Physiochemical Properties of Guar Gum

Components	Percentage	Composition role
Protein	3.5-4.0%	Cellular, Functional
Water soluble polysaccharides	86.50%	Structural
Phosphorus	0.06%	Structural
Alcohol soluble fraction	1.50%	Functional
Water insoluble fraction	7.75%	Functional
Ash	1.07%	Physiochemical
Moisture	10 %	Physiochemical
Lipids	1.2%	Cellular, Structural

2.1 Chemical Structure

Guar gum or galactomannan also known as Guaran, Calcutta lucerne, Cluster bean, Cyamopsis gum, Guarina, Guyan, Glucotard and Gum Cyamopsis. It is natural water soluble, non-ionic polysaccharide obtained from the endosperm of *Cyamopsis tetragonoloba* seeds (Gresta *et al.*, 2017). Cluster bean gum is galactomannan which is similar to gum of locust bean comprising of α-1, 4-linked β-Dmannopyranose backbone with the branched points from their 6-position linked to α-D-galactose (for example, 1, 6-linked-α-Dgalactopyranose). The chemical structure of guar is shown in figure 1.

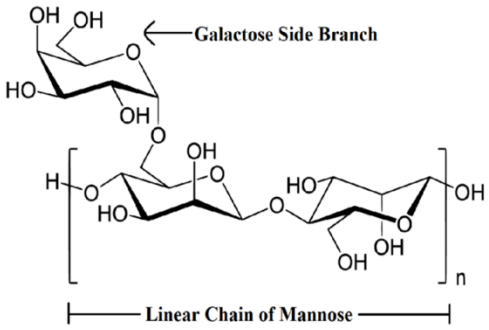

Figure 1: Shows the chemical structure of guar

3. Production of Guar

Guar is a scarcity resilient crop which is mainly grown in Pakistan and North-west India (Henry *et al.*, 1986). As shown in Fig. 2.1. The contribution of India in production of guar is 80% and produced annually 1 to 1.25 million tons of guar. And as shown in Fig. 2.2 and 2.3 Pakistan produces 0.118 million tons and accounts for 15% of the world's supply of cluster bean with 0.31275 million tones being exported to the Europe and USA (Jitender *et al.*, 2014). Although Pakistan and India are the world largest producers of guar gum and the other countries like China, Australia, USA, as well as some African continents produce smaller amount of guar gum. Due to the increase in consumption of guar gum at industrial level about 45 percent of total world demand for guar gum also increased. In 1945, locust bean gum supply become short due to 2nd World War, and therefore the gum obtained from guar was considered as a better alternative for locust bean gum. The Purdue University grows and experimented mature guar seeds. In 1953, guar gum became commercially available and its various uses in food were also investigated (Manoj *et al.*, 2018; Kandel *et al.*, 2018).

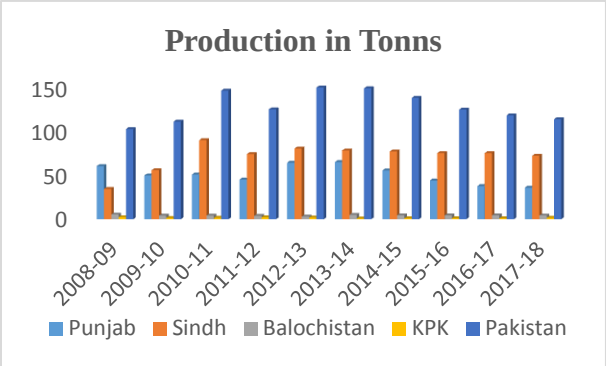

Figure 2: Shows the production of guar in tons in Pakistan

4. Cultivation in Pakistan

For green pods as vegetable the guar is grown from February to March and there will be more chance to make more money by selling green pods. For seed purpose, best time for guar sowing is May-July but for green manuring and green fodder, the sowing is done during the months of April-July. In rain fed areas the crop is sown after monsoon rains (Kapoor, 2014). Cultivation of cluster bean in Pakistan for its best growth requires full sunshine, flushing rainfalls that are moderately frequent. The most important growing areas in Pakistan are Punjab, Muzaffargarh, Multan, Layyah, Mianwali, Bahawalpur, Sargodha, Bahawalnagar and Sindh province. Cluster bean is grown in almost 0.1925-million-hectare area in Pakistan. Fig. 2 reveals that the Punjab and Sindh provinces have greater cultivated area than KPK and Balochistan provinces. For seed purpose 20-kilogram seed per hectare is enough. For green manuring or fodder purpose seed rate is kept

about 40-kilogram per hectare. Under late sowing condition, soil salinity or alkalinity conditions, dry condition seed rate is normally increased. Broadcasting method is done if the crop is sown for fodder purposes but if the crop is sown for grains purpose, then drilling is better and proved better for seed germination. The spacing of 9-inch between plants and 1.5 feet between rows is given for seed purpose (Kumar and Ram, 2015; Meftahizadeh *et al.*, 2019).

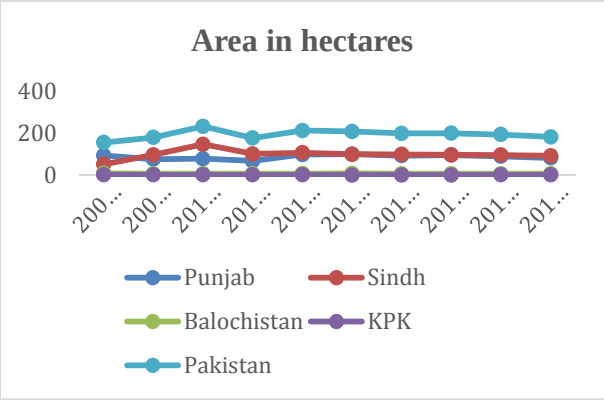

Figure 3: Shows the cultivation of guar in hectares in Pakistan

5. Botanical Significance of Guar

Cluster bean is a robust annual plant with a long tap root and well-developed laterals. It generally grows 50-90 cm tall and remains unbranched where the main stem is heavily clustered with pods. Branching habits in guar may be grouped into one of three classifications: erect, basal branching and branching along the main stem (Menon *et al.,* 1977). The leaves of this arid legume are alternate, trifoliate which are borne on long petioles. The stem is tall and slender. Stipules are linear, subulate and persistent. Leaflets elliptical, 5-7 x 2-4 cm acute at base and apex, dentate, clothed on both surfaces with white hairs. The flowers of this crop borne in the axil. The five uneven sepals form the calyx which are linear and teeth type. Corolla is orbicular, standard with long wing petals & long and broad keel petals. purplish to pink flowers are present in guar. There are 10 diadelphous stamens in which apicular anther is present, style is cylindrical and short, fertile stigma is head shaped (Mital and Thomas, 1969; Morris, 2010). The 4-10cm long oblong shaped pods, containing 5-12 cube or oval shaped grains of variable shape. Its seed contains three parts 14-17% seed coat, 35-42% endosperm and 43-47% embryo. Most of the protein is contained in the germ (embryo). Guar seeds are nearly round shaped with a 100 seed weight of 3.0 g. The crop due to cleistogamous nature is considered strictly self-pollinated, however, out crossing to the tune of 0.5 to 7.9% has been reported (Muthuselvi *et al.,* 2017). Guar cultivation started from the area of Pakistan and India and hence it is an erect bushy short day annual plant with drought resistance (Ogwu *et al.,* 2014).

Endosperm of guar seed contained galactomannan gum. The color of guar seed ranged from black to dull white. Seed coat pigments consisted of galactose, gallic acids, ferric ions and 2, 3, 4-trihydroxybenxoic acids. Seed coat color of the common bean is reported to be genetically controlled, and has been investigated the seed is affected by the environmental conditions. There are no reports of seed coat color effect on seed quality with regard to germination and gum content (Patil, 2014).

6. Emerging Roles

It is broadly favored for its viscous properties. Galactomannan as a disintegrator and binder is mainly used in manufacturing of tablets. The item for consumption achieved from the grains of guar crop is also an active stabilizer and thickener. Galactomannan is an effective source to control diabetes so supports in control of the prolonged disease mainly cancer and obesity. It is very effective in losing weight. As diet preservative, it reduces hunger. It is a valuable item for consumption for colon purgative and aid in washing the intestinal system. It also has pharmacological properties and consequently favored in numerous therapeutic formulations in

dispensary (Phougat *et al.,* 2017; Rai and Dharmatti, 2014).

6.1 Guar Gum In Drug Delivery

The galactomannan consumption orally recognized as harmless, therefore in pharmaceutical industries it is widely used as stabilizing, binding, suspending, thickening, and as an emulsifying agent (Reddy *et al.,* 2018). Also due to its lower antigenicity it is used in the healing of wounds. The enzymatic-degradation and gelling properties and the comprehensive regulatory reception of the GG have enabled its recognition as very latent drugs delivery carrier. Due to its greater use's galactomannan achieve an appropriate and cost-effective drugs release profile, it is used broadly and in varied forms like nanoparticles, nanocomposites, hydrogels, nanofibers, tablets matrix, etc. for besieged drug delivery. All these systems of delivering drugs offered the drugs protection against the prolong biological activities, degradation and enhances the therapeutic effects (Sanghi *et al.,* 1964; Santhosha *et al.,* 2017).

6.2 Guar Gum In Treatment Of Diabetes

Many of the investigations showed that the guar gum decreased postprandial rise in the blood-glucose and the concentrations of insulin. The mixture of guar gum and pectin for hyperlipidemia treatments. They investigated that the total level of cholesterol and the concentration of triglyceride in blood-serum is dropped but HDL cholesterol-level remained almost same in the fifteen female patients (52- to 70-year-old) having type-2-diabetes with the hypercholesterolemia (total Chol. > 240 mg/dl and LDL Chol. > 130 mg/dl). The females were taken mixture of fiber at dose level (17gm + 5.9gm water soluble fiber) dissolved in the 250ml of water for nine weeks, after three weeks in dietetics run in phase. PHGG (partially hydrolyzed guar gum) is regarded as harmless and better to use as food for dropping of lipids in the patients who are suffering from the hyperlipidemia (Shoran, 1982; Sohoo and Bhardwaj, 1985).

6.3 Guar Gum In Treatment Of Cancer

Colon cancer is 3rd most serious kind of cancer with 665,000 expiries/year globally. The assessed the effects of glutaraldehyde cross-linked guar gum comprising methotrexate for the treatment of colon cancer (colorectal cancer). The anti-inflammatory and the chemo-preventive properties of guar gum by using its derivatives. They described that the altered guar gum has ability to prevent the cancer and requirement as a supplement in the foods (Solanki and Choudhary, 1996; Staffor and Seiler, 1986). The consequences showed that the guar gum derivatives have the ability to stop the carcinogen-activator-enzyme, cytochrome-P450-1A (CYP1A), and also promote carcinogen-detoxification-enzymes glutathione S transferases (GSTs) (Tikka, 1975; Vir and Singh, 2015).

6.4 Guar Gum-Based Hydrogels For Water Purification

In the purification of water, adsorption mechanism is used. For this method, chemical modifications and number of fillers have been examined to attain the obligatory applications in th water remedy programs (Dhami *et al.*, 2018).. The hydrogels built on modified-guar-gum-polyacrylamide m-(GG-Poly-AAm) and guar-gum polyacrylamide (GG-Poly-AAm) were utilized for assessing the exclusion percentage of crystal violet dyes and azure-B. Glutaraldehyde and methylene bis-acrylamide were utilized as a cross linkers for the attainment well-linked network (Phougat *et al.,* 2017; Rai and Dharmatti, 2014).

6.5 Role of Nanocomposites

The different researchers investigated that for detecting the level of low ammonia in the humans we could easily use the room temperature optical ammonia sensing of the medical and clinical diagnosis in near future. For the synthesis of gold nanoparticles, an eco-

friendly and low-cost method is used which involved the guar gum as reducing agent. Guar gum/gold nanoparticles nanocomposite (GG/AuNPs NC) are subjugated for the optical sensing for the detection of aqueous-ammonia on the bases of SPR (surface plasmon resonance) (Solanki and Choudhary, 1996; Staffor and Seiler, 1986). The researchers investigated that this method might be used for quick production of very cost Guar gum/gold nanoparticles nanocomposite based aqueous-ammonia sensor (Ahmed *et al.,* 2003).

The adsorption rate was noted maximum at 50 minutes contact-time, 25mg per liter of Cr (VI) concentration, 1.0g per liter of adsorbent dosage and at 7.0 ph. It was noted that nano-zinc-oxide bio-composite adsorbent exhibited an enhanced capacity of adsorption for the Cr (VI) as compared to the other adsorbents stated in literature. The results revealed that nano-zinc-oxide bio-composite is economically eco-friendly and has ability to remove the Cr (VI) from the natural water-resources. The guar gum proved very helpful in Ag-clusters binding and also helps to reduce their size at the nano region. From thermo-gravimetric analyses it had been proved that the incorporation of the nano size Ag-clusters with in guar-gum enhanced the thermal-properties of the irradiated-guar-gum. Guar gum stabilized Cu-nanoparticles catalyst for the cyclo-addition reactions were manufactured (Manoj *et al.,* 2018; Kandel *et al.,* 2018). To affirm the morphology of manufactured nanoparticles, SAED (selected area electron diffraction) analyses of samples was carried out and it was investigated that particles were crystal-like in nature that was additionally confirmed by the X-ray-diffraction (Solanki and Choudhary, 1996).

6.6 Guar a Forage

Guar is the good nutritious fodder source for cattle, but due to the presence of hydrocyanic acid in guar pods, only mature pods can be consumed. Guar plantation increases the yield of subsequent reaps as this crop conserves soil nutrients content. Its leaves can be consumed as spinach, and the pods are used as vegetables or salad. Its pods are nutritious, but protein present in guar is not digestible by humans unless toasted to destroy the trypsin inhibitor (Muthuselvi *et al.,* 2017).

6.7 Food Applications

In cheeses, it is used for the elimination of syneresis. In pastry icing it decreases absorption of water by sucrose; and in baked goods it increases long shelf life. It is also used in meat goods to improve casing stuffing. When it is used in sauces and dressings at level of 0.2 to 0.8%, it adds to pleasant mouth feel and also increases viscosity (Menon *et al.,* 1977). Today guar plant is cultivated as a source of guar gum and it is a multi-purpose plant. The galactomannan gum obtained from guar plant is a stabilizing and thickening agent which is used in different food additives like ice cream, yoghurt, salad and dressings. The guar gum and the other water-soluble resins obtained from guar grains are also used in many other big industries, such as oil well drilling, paper forming industries, mining, tobacco and cosmetics industries (Solanki and Choudhary, 1996; Staffor and Seiler, 1986).

Table 2: Shows the Applications Of Guar And Related Compounds

Food	Dose level	Function
Bread	0.5%	Softness, loaf volume
Chapati	0.75%	
Fried Products	0.5–1.0%	Softness
Cake	0.15%	Oil uptake reduction
Yoghurt	2.0%	
Pasta	1.5%	Fat replacer,
Sausage	0.13–0.32%	Firmness
Baked goods	1.0%	Texture improver

6.8 Guar as Meal

It is 100% ordinary agricultural product, non-Genetically Modified Organism, chemical substances and preservatives-free food material. It decreases the prices of feed manufacture (Phougat *et al.,* 2017). It is obtained from guar seed and chiefly used as a significant raw agent in animal feeding industries, especially in swine feeding, cattle feeding, poultry feeding and fish feeding etc. It is obtained from guar seeds. For the use of poultry, it can be applied in the range of 5-8%, pig feed can be used between 6-8% and it is safe to feed ruminants when it is applied between 6-11% (Mital and Thomas, 1969; Morris, 2010).

7. Conclusion

Guar is an important economical fodder crop to maintain the standards of livestock population, to strengthen the economy and to meet the requirement of livestock population, need to enhance the germplasm and creating genetic variability in guar accessions for both qualitative and quantitative traits characters. Due to its nutritive value and pharmacologic activities, it can used to treat the infections caused by bacteria and viruses.

8. References

Ahmed, H. M., Khan, B. M., Khan, S., Kissana, N. S., & Laghari, S. (2003). Path coefficient analysis in bread wheat. Asian Journal of Plant Sciences, 2: 491-94.

Bhujel, J., Sharma, S., Shrestha, J., & Bhattarai, A. (2018). Correlation and path coefficient analysis in normal irrigated rice (Oryza sativa L.). Farming and Management, 3(1), 19-22.

Brooker, R. J., (2005). Genetics: Analysis and Principles. (2nd Ed). McGraw-Hill, New York, U.S.A.

Chavan, S. K., Mahajan, R. C., & Fatak, S. U. (2010). Genetic variability studies in sorghum. Karnataka Journal of Agricultural Sciences, 23(2), 322-323.

Crossman, A. (2017). Understanding path analysis: a brief introduction.

Dewey, D. R., & Lu, K. (1959). A correlation and path- coefficient analysis of components of crested wheatgrass seed production 1. Agronomy journal, 51(9), 515-518.

Dhami, N. B., Kandel, M., Gurung, S. B., & Shrestha, J. (2018). Agronomic performance and correlation analysis of finger millet genotypes (Elusine coracana L.). Malaysian J. Sustain. Agric, 2, 16-18.

Ghimire, S., Khanal, A., Kohar, G. R., Acharya, B., Basnet, A., Kandel, P., ... & Dhakal, K. (2018). Azarian Journal of Agriculture, 5: 7-11.

Gresta, F., Ceravolo, G., Presti, V. L., D'Agata, A., Rao, R., & Chiofalo, B. (2017). Seed yield, galactomannan content and quality traits of different guar (Cyamopsis tetragonoloba L.) genotypes. Industrial Crops and Products, 107, 122-129.

Henry, A., Daulay, H. S., & Krishna, G. V. S. R. (1986). Correlation, path coefficient analysis and genetic diversity in cluster bean. Madras Agric. J, 73(1), 11-16.

Jitender, S. P., Verma, N. A. R. E. S. H., & Bhusal, N. A. B. I. N. (2014). Genetic variability and heritability for seed yield and water use efficiency related characters in cluster bean [Cyamopsis tetragonoloba (L.) Taub.]. Forage Research, 39(4), 170-174.

Kandel, M., Ghimire, S. K., Ojha, B. R., & Shrestha, J. (2018). Correlation and path coefficient analysis for grain yield and its attributing traits of maize inbred lines (Zea mays L.) under heat stress condition. International Journal of

Agriculture Environment and Food Sciences, 2(4), 124-130.

Kapoor, R. (2014). Genetic variability and association studies in guar [Cyamopsis tetragonoloba (L.) Taub.) for green fodder yield and quality traits. Electronic Journal of Plant Breeding, 5(2), 294-299.

Kumar, V., & Ram, R. B. (2015). Genetic variability, correlation and path analysis for yield and yield attributing traits in cluster bean [Cyamopsis tetragonoloba (L.) Taub.] genotypes. Int. J. Pure App. Biosci, 3(1), 143-149.

Manoj, K., Ghimire, S. K., Ojha, B. R., & Shrestha, J. (2018). Genetic diversity for heat tolerant related traits in maize inbred lines. Agricultura, 105(1-2), 23-34.

Mathur, M. L., & Mathur, R. (1981). Inter-relationship among yield and yield components in grain varieties of Cyamposis tetragonolo+ ba (L.) Toub. Madras agricultural journal, 68: 594-598.

Meftahizadeh, H., Ghorbanpour, M., & Asareh, M. H. (2019). Changes in phenological attributes, yield and phytochemical compositions of guar (Cyamopsis tetragonoloba L.) landaraces under various irrigation regimes and planting dates. Scientia Horticulturae, 256, 108577.

Menon, U., Dubey, M. M., & Kala, K. C. (1977). Path coefficient analysis in guar (Cyamopsis tetregonoloba L. Taub.)[India]. Indian Journal of Heredity, 9: 21-23

Mital, S. P., & Thomas, T. A. (1969). Correlation and selection indices in improvement of seed yield in guar. Indian J. Genet, 29(1), 10-17.

Morris, J. B. (2010). Morphological and reproductive characterization of guar (Cyamopsis tetragonoloba) genetic resources regenerated in Georgia, USA. Genetic resources and crop evolution, 57(7), 985-993.

Muthuselvi, R., Shanthi, A., & Praneetha, S. (2017). Genetic association of yield and yield attributing characters in cluster bean [Cyamopsis tetragonoloba (L.) Taub.]. Int. J. Chem. Stud, 5(4), 1934-1936.

Ogwu, M. C., Osawaru, M. E., & Ahana, C. M. (2014). Challenges in conserving and utilizing plant genetic resources (PGR). International Journal of Genetics and Molecular Biology, 6(2), 16-23.

Patil, D. V. (2014). Genetic Variability and Sowing Dates Effect of Cluster Bean (Cyamopsis tetragonoloba L., Taub) Genotypes in Semi Arid Region of Maharashtra, India. Plant Archiv, 14(1), 1-6.

Phougat, D., Panwar, I. S., Saharan, R. P., Singh, V., & Godara, A. (2017). Genetic diversity and association studies for yield attributing traits in bread wheat [Triticum aestivum (L.) em. Thell]. Research on Crops, 18(1), 139-144.

Rai, P. S., & Dharmatti, P. R. (2014). Correlation and path analysis for cluster bean vegetable pod yield. The bioscan, 9, 811-814.

Reddy, B. J., Mandal, R., Chakroborty, M., Hijam, L., & Dutta, P. (2018). A review on potato (Solanum tuberosum L.) and its genetic diversity. International Journal of Genetics, ISSN, 0975-2862.

Sanghi, A. K., BHATNAGA. MP, & Sharma, S. K. (1964). Genotypic and phenotypic variability in yield and other quantitative characters in guar. Indian Journal of Genetics and Plant Breeding, 24(2), 164.

Santhosha, G. R., Shashikanth, E., Gasti, V. D., Prabhuling, G., Rathod, V. D., & Mulge, R. (2017). Genetic variability studies in

cluster bean [Cyamopsis tetragonaloba (L.) Taub.] for growth, yield and quality parameters. Legume Research-An International Journal, 40(2), 232-236.

Shoran, J. (1982). Path analysis in pigeonpea. Indian Journal of Genetics and Plant Breeding, 42: 319-321.

Sohoo, M. S., & Bhardwaj, B. L. (1985). Path coefficient analysis of seed yield in clusterbean. Note. Crop Improvement, 85-86.

Solanki, Z. S., & Choudhary, B. R. (1996). Stability analysis in clusterbean (Cyamopsis tetragonoloba). Indian Journal of Agricultural Sciences, 66(8), 470-473.

Stafford, R. E., & Seiler, G. J. (1986). Path coefficient analyses of yield components in guar. Field crops research, 14, 171-179.

Tikka, S. B. (1975). Interrelationship between yield and components in clusterbean. Indian J. Genet. Plant Breed, 35, 340-343.

ttp://www.djsresearch.co.uk/glossary/item/correlation-analysis-market-research

Vir, O., & Singh, A. K. (2015). Variability and correlation analysis in the germplasm of cluster bean Cyamopsis tetragonoloba (L.) Taub.] in hyper hot arid climate of Western India. Legume Research-An International Journal, 38(1), 37-42.