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Mustard as Medicinal Plant: Sources, Botanical Features, Genetics and Applications

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Abstract

Mustard as the medicinal plant used for the treatment of various diseases. There are 3 types of mustard: brown, oriental and yellow. Generally, the mustard seeds are mainly used in condiment or food industries in either oil or seeds form. The mustard plant is a plant species belongs to family Brassicaceae and the genera Brassica. The seed of mustard is used as spice. Derivatives of mustard constituent's allyl iso-thiocyanate form basis for deadly agents such as anti-neoplastic drugs (e.g. bendamustine) and mustard gases. It helps for karyotyping process that centered on meiotic and mitotic chromosome and used many methods of staining comprising CMA3/DAPI fluorescence staining, Giemsa staining, silver staining, C banding, and fluorescence in situ hybridization with repetitive DNA sequences. As a source of vitamin-K plays its important role in serving with the blood clotting. It is also important and essential for the health of bone and heart. All these mustard species can also be utilized in the production of eatable oils. Both oriental and brown mustards are utilized to make the products which are spicier than the condiments which obtained from yellow mustard.

Keywords: Mustard plant, role, biochemical applications, chemical composition, genetics.

INTRODUCTION

The mustard plant is a plant species belongs to family Brassicaceae and the genera Brassica and Sinapis. The seed of mustard is used as spice. The seeds are grinded and mixed with vinegar, water and other liquids makes a yellowish colored condiment which is known as prepared mustard. The green leaves of mustard are used as vegetable and by pressing its seeds we obtain mustard oil.

Mustard is a short growing season crop and it is cultivated in cool crop period. Its seedlings are most tolerant to the mildly frosts but the serious frost conditions effects hardly. During reduction stage, humidity stress caused by the dry and hot conditions frequently causes lowered yield [1,2,3,4].

The seeds, leaves, and the seeds oil is used in many medicines. Derivatives of mustard constituent's allyl iso-thiocyanate form basis for deadly agents such as anti-neoplastic drugs (e.g. bendamustine) and mustard gases. Mustard is used in flavoring of food, as fodder, as diuretic and an emetic, and also used in treatment of inflammatory infections such as rheumatism and arthritis. Mustard plant has potential pharmacological properties in the cardiac diseases, diabetes and cancer; though, there are partial clinical tribunals to support its use for any of suggestion [5,6,7,8].

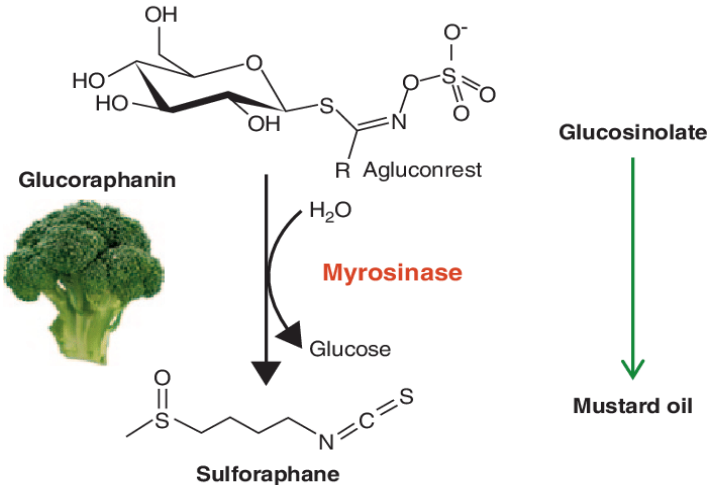

Fig-1: Shows the formation of mustard based product and related compounds

There are some side effects of mustard. If someone takes greater amount of seeds of black mustard by mouth can greatly damage the throat and many other serious side effects like diarrhea, breathing difficulties, heart failure, coma, drowsiness and also death. When it is applied to skin, particularly for long time, the black mustard cause damage of skin and skin blisters. Brown mustard is an important crop as it is a source of vegetable oil and it is related to the rapeseed and is cultivated in Pakistan, India, Kazakhstan and southern Russia for this purpose. Oil from its seeds has great values as it is used in many foods and in many animal feeding and human feed industries [9,10].

Sources of Mustard Plant

There are 3 types of mustard: brown, oriental and yellow. Generally, the mustard seeds are mainly used in condiment or food industries in either oil or seeds form. Yellow mustard is mildest of three and also has very low content of oil. It is frequently used in production of “mild” prepared mustard for the table usage but also used as dry mustard in mayonnaise, dressings, sauces and salads. The flour obtained from the yellow mustard is a good stabilizing and emulsifying agent and it is used as stabilizer and emulsifier in prepared meats. Oriental and brown mustard are mainly used as “hot” table mustard and also for spices and for oil. The flowers and leaves of brown mustard plant are consumed as salad greens [11, 12].

Brassica carinata A. Braun., which is known as the Abyssinian or Ethiopian mustard, a local traditional vegetable of Africa and it is grown in Ethiopian uplands. It is believed to be an amphidiploid among Brassica oleracea and Brassica nigra. For its seeds it is sown during spring in New Zealand and Canterbury[13]. The plant is extensively used as a bio fumigant, to overwhelm soil borne pathogens and pests and due to this reason it is cultivated as rotation crop in New Zealand and Australia. It is native to Eurasia and Southeast Asia, commonly cultivated in temperate northern areas comprising northern Asia, Korea, Japan, Scandinavia, Russia and Northern China. In Australia, Brassica napus inhabited in New South Wales, Victoria, Queensland, and Western Australia, and Southern Island territories of Canterbury and Marlborough in New Zealand. In Australia, napus (coleseed or rape) and naprobrassica L. are two maximum grown varieties and frequently used as fodder, in medicines and in the production of oil from them. In New Zealand and Australia Brassica napus is extensively used in soups, stews and as aromatic constituent [14].

Genetics of Mustard

The evolutionary relations between these species of Brassica are described by what is called the 'triangle of U' model 2, which suggests how genome of three ancestral species of Brassica, Brassica oleracae, Brassica rapa, and Brassica nigra joined to give-rise the allopolyploid species of this genus. By hybridization of Brassica nigra and Brassica rapa diploid ancestors, and followed by the spontaneous doubling of chromosomes the Brassica juncea is formed. Succeeding varying selection then to give-rise the oil use and vegetables sub-varieties of Brassica juncea. For the study of cytogenetic, karyotyping is a best tool, which showed the characteristics and chromosomes number and it can be used to clarify the ploidy, phylogenetic relationship and origin between plant species. Numerous karyotypes issued for the Brassica species, commonly related to Brassica napus, Brassica oleracea and Brassica rapa that are of chief agronomic attention. In earlier investigations, karyotyping was centered on meiotic and mitotic chromosome and used many methods of staining comprising CMA3/DAPI fluorescence staining, Giemsa staining, silver staining, C banding, and FISH (fluorescence in situ hybridization with repetitive DNA sequences) [15,16,17,18,19,20].

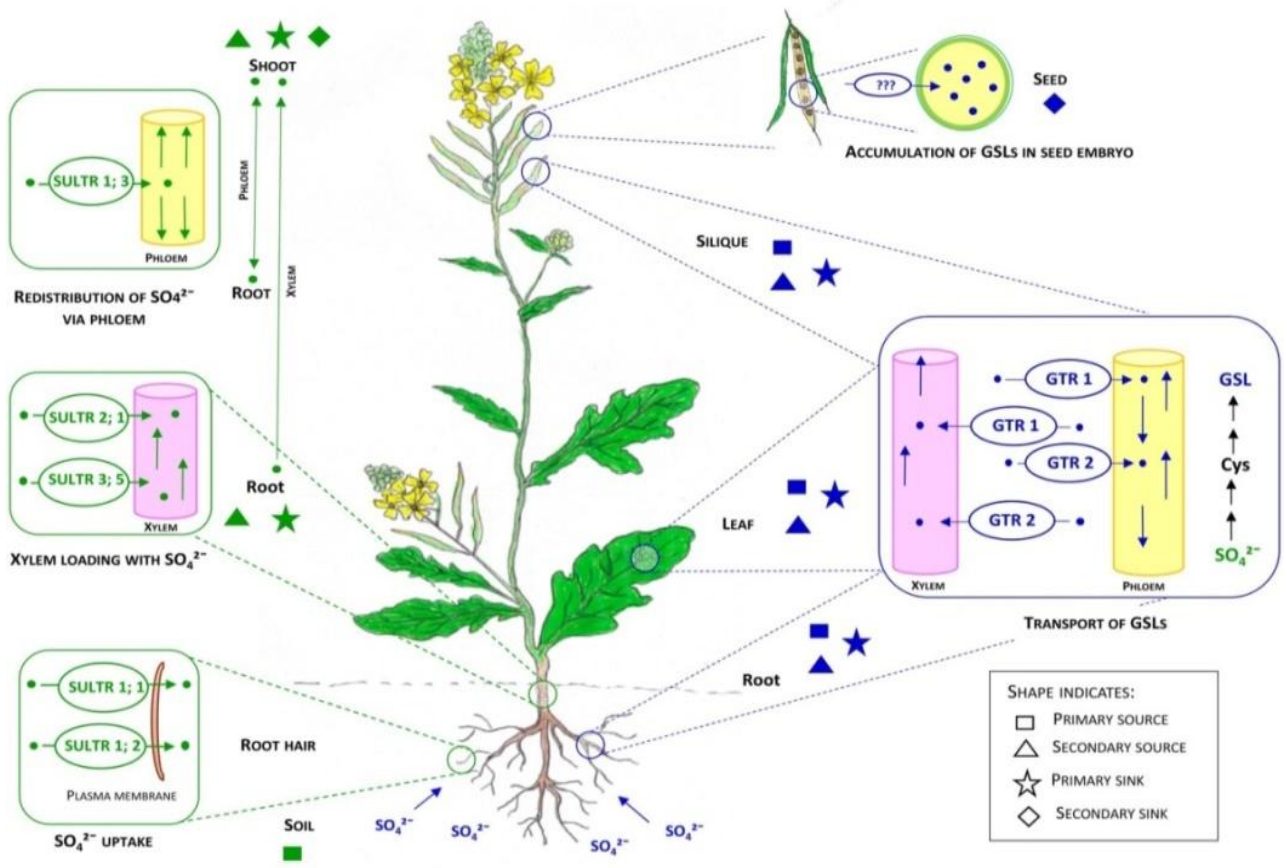

Fig-2: Shows the genetics of mustard and activation of gene complex

Uses/applications of Mustard

Excellent source of vitamin K

Both the cooked and raw mustard greens are the major sources of vitamin-K, and provides 120 percent and 690 percent of DV per 1 teacup (56 g & 140 g), correspondingly. The vitamin-K play its important role in serving with the blood clotting. It is also important and essential for the health of bone and heart [21, 22].

Rich in disease-fighting antioxidants

The antioxidants are natural compounds obtained from plants which gives protection against the oxidative stresses that are caused due to excessive amount of the free radicals. These radicals are unbalanced molecules and can harm your cells. Many of the researches advocates that with the passage of time, this injury can lead to the serious diseases like cancer, Alzheimer and heart diseases. Whereas the levels of particular anti-oxidants vary among different mustard green varieties, generally, these mustard greens are the enriched source of anti-oxidants such as lutein, flavonoids, vitamin E and C and beta carotenes[23, 24].

Other important uses

All these mustard species can also be utilized in the production of eatable oils, and on the subcontinent of India, the Brassica juncea seeds are utilized in the production of 2nd most essential source of cooking oil[25-28]. Mustard plant is also a chief source of best quality proteins, and after the withdrawal of this oil, the remaining higher proteins meal can be soaked in the water and then fed to the livestock. The mustard plant leaves, called the mustard greens, and these are utilized as food. Additionally, both the leaves and seeds of mustard conventionally used for the curative purpose, comprising the historic use as remedial for common cold and utilization in cures for chilblains, baths, and mustard plasters. The recent researches on the mustard plant that have high oil quality and quantity are used in the production of bio-diesel, a renewable liquefied fuel which is similar to diesel. The bio-diesel which is obtained from mustard oil has noble cetane rating and cold flow properties. The remaining meal after the extraction of oil used as an effective pesticide [29-35].

Farmers choose the delayed flowering varieties of mustard that do not produce the seeds; these may developed into weeds in the succeeding years [36-39]. The early vigor is essential for quickly soil covering and suppressed the weeds and also gives protection against the erosion of soil. In rotations with the sugar-beets, the suppression of white-beet cyst-nematode is important character. Resilient varieties of white mustard reduce the population of nematode by 70 to 90 %. A heritable relationship among the many mustard species,

along with the cabbage, turnips and their corresponding derivatives [40-43].

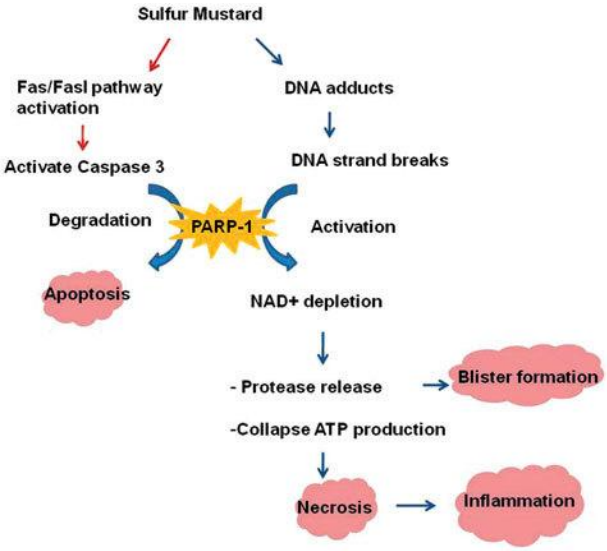

Fig-3: Shows the role of mustard in activation of inflammation response

The yellow seed coat is present in yellow mustard and it is primarily cultivated for condiment industries in North-America, where it is utilized in the production of traditionally used yellow mustard condiment, in salad dressings and in mayonnaise [44-48]. A water binding mucilage is present in yellow mustard seeds, which used as binding agent and as extender of protein in prepared meats. Hybrid-brow and brown mustard have reddish-brown to dark-brown seed-coat whereas the seeds of oriental mustard are yellow to dark-yellow [49-52]. Both oriental and brown mustards are utilized to make the products which are spicier than the condiments which obtained from yellow mustard. Brown mustard is mostly exported to the European countries where it is utilized in the production of condiments and specialty-mustard like Dijon-mustard. The oriental mustard is mainly cultivated for export to the Asian countries, where it is also used in the production condiments [53-56]. The oil of oriental mustard is used as spiced cooking oil in the Asian countries, but it is not eaten as oil in the North America [57-58].

CONCLUSION

Transgenic mustard plants shows the overexpressing pea seed ferritin cDNA under the control of CaMV35S promoter. Manipulation of ferritin expression in various plants has already proved that biotechnological approaches have an edge over conventional techniques in solving dietary Fe deficiencies. The characteristic seed shedding and seed dormancy of black mustard made it unsuited to monoculture and mechanized agriculture.

REFERENCES

1. Wang, J., Hu, M., Wang, J., Qi, J., Han, Z., Wang, G., ... & Chai, J. (2019). Reconstitution and structure of a plant NLR resistosome conferring immunity. Science, 364(6435).
2. Papazian, S., Girdwood, T., Wessels, B. A., Poelman, E. H., Dicke, M., Moritz, T., & Albrectsen, B. R. (2019). Leaf metabolic signatures induced by real and simulated herbivory in black mustard (Brassica nigra). Metabolomics, 15(10), 1-16.
3. Zwolińska, A., Krawczyk, K., Borodynko-Filas, N., & Pospieszny, H. (2019). Non-crop sources of Rapeseed Phyllody phytoplasma ('Candidatus Phytoplasma asteris': 16SrI-B and 16SrI-(B/L) L), and closely related strains. Crop Protection, 119, 59-68.
4. Zwolińska, A., Krawczyk, K., Borodynko-Filas, N., & Pospieszny, H. (2019). Non-crop sources of Rapeseed Phyllody phytoplasma ('Candidatus Phytoplasma asteris': 16SrI-B and 16SrI-(B/L) L), and closely related strains. Crop Protection, 119, 59-68.
5. Zhang, H., Zhao, Z., Zhang, X., Zhang, W., Huang, L., Zhang, Z., ... & Liu, X. (2019). Effects of foliar application of selenate and selenite at different growth stages on Selenium accumulation and speciation in potato (Solanum tuberosum L.). Food chemistry, 286, 550-556.
6. Poret-Peterson, A. T., Albu, S., McClean, A. E., & Kluepfel, D. A. (2019). Shifts in soil bacterial communities as a function of carbon source used during anaerobic soil disinfestation. Frontiers in Environmental Science, 6, 160.
7. Harahap, F. S., & Sari, P. M. (2019). Growth and production response of plant pakcoy (brassica rapa l) on use of nasa light organic fertilizer. Jurnal Pertanian Tropik, 6(2), 222-226.
8. Shahid, A., Ali, S., Zahra, T., Raza, M., Shahid, A., Saeed, M. U., & Javaid, F. Influence of Microbes in Progression of Cancer and DNA Damaging Effects.
9. Iftikhar, A., Shahid, A., Shah, S. S., Ali, S., Raza, M., Ali, E., & Umbreen, S. Antimicrobial Activities of Selected Medicinal Plant with Potential Role of Chemical Compounds.
10. Naeem, M., Hayat, M., Qamar, S. A., Mehmood, T., Munir, A., Ahmad, G., ... & Hussain, A. (2019). Risk factors, genetic mutations and prevention of breast cancer. Int. J. Biosci, 14(4), 492-496.
11. Shafiq, S., Adeel, M., Raza, H., Iqbal, R., Ahmad, Z., Naeem, M., ... & Azmi, U. R. (2019). Effects of Foliar Application of Selenium in Maize (Zea Mays L.) under Cadmium Toxicity. In Biological Forum-An International Journal (Vol. 11, No. 2, pp. 27-37).
12. Guo, D., Ali, A., Ren, C., Du, J., Li, R., Lahori, A. H., ... & Zhang, Z. (2019). EDTA and organic acids assisted phytoextraction of Cd and Zn from a

smelter contaminated soil by potherb mustard (Brassica juncea, Coss) and evaluation of its bioindicators. Ecotoxicology and environmental safety, 167, 396-403.
13. Ahmad, I., Khan, S., Naeem, M., Hayat, M., Azmi, U. R., Ahmed, S., ... & Irfan, M. (2019). Molecular Identification of Ten Palm Species using DNA Fingerprinting. Int. J. Pure App. Biosci, 7(1), 46-51.
14. Usman, G., Muhammad, N., Hamza, R., Usman, I., Ayesha, A., Saqib, U., ... & Fatima, Q. (2019). A Novel Approach towards Nutraceuticals and Biomedical Applications. Scholars International Journal of Biochemistry, 2(10), 245-252.
15. Naeem, M., Ali, J., Hassan, M. Z., Arshad, B., Rao, M. H. I., Sarmad, M. S. K., ... & Hassan, M. U. (2019). Novel Approach towards DNA Barcoding as a Tool in Molecular Biologyand Biological Activities of Cyclotides with Particular Emphasizes at Molecular Level. In Biological Forum-An International Journal, 11(2), 83-96.
16. Teklehaymanot, T., Wang, H., Liang, J., Wu, J., Lin, R., Zhou, Z., ... & Wang, X. (2019). Variation in plant morphology and sinigrin content in Ethiopian mustard (Brassica carinata L.). Horticultural Plant Journal, 5(5), 205-212.
17. Shakeel, A., Khan, A. A., & Ahmad, G. (2019). The potential of thermal power plant fly ash to promote the growth of Indian mustard (Brassica juncea) in agricultural soils. SN Applied Sciences, 1(4), 1-5.
18. Naeem, A., Saddique, S., & Chand, S. A. (2019). Advancement and Future Directions towards Herbal Treatment for Various Diseases.
19. Shakeel, A., Khan, A. A., & Ahmad, G. (2019). The potential of thermal power plant fly ash to promote the growth of Indian mustard (Brassica juncea) in agricultural soils. SN Applied Sciences, 1(4), 1-5.
20. Naeem, M., Ashraf, A., Safdar, H. M. Z., Khan, M. Q., Rehman, S. U., Iqbal, R., & Ahmad, G. (2020). Biochemical changes in patients with chronic kidney failure in relation to complete blood count and anemia. IJB, 16(1), 267-271
21. Gurajala, H. K., Cao, X., Tang, L., Ramesh, T. M., Lu, M., & Yang, X. (2019). Comparative assessment of Indian mustard (Brassica juncea L.) genotypes for phytoremediation of Cd and Pb contaminated soils. Environmental Pollution, 254, 113085.
22. Naeem, M., Hussain, A., Azmi, U. R., Maqsood, S., Imtiaz, U., Ali, H., ... & Ghani, U. (2019). Comparative Anatomical Studies of Epidermis with Different Stomatal Patterns in Some Selected Plants Using Compound Light Microscopy. International Journal of Scientific and Research Publications, 9(10), 375-380.
23. Ahsan, M., Aslam, M., Akhtar, M. A., Azmi, U. R., Naeem, M., Murtaza, G., ... & Shafiq, S. (2019). Effect of inoculation of three rhizobial strains on maize hybrids. Journal of Biodiversity and Environmental Sciences, 14(6), 168-177.
24. Hazafa, A., Batool, A., Ahmad, S., Amjad, M., Chaudhry, S. N., Asad, J., ... & Ghani, U. (2020). Humanin: A mitochondrial-derived peptide in the treatment of apoptosis-related diseases. Life Sciences, Volume 264, 2021, 118679.
25. Rafeeq, H., Ahmad, S., Tareen, M. B. K., Shahzad, K. A., Bashir, A., Jabeen, R., ... & Shehzadi, I. Biochemistry of Fat Soluble Vitamins, Sources, Biochemical Functions and Toxicity. Haya: The Saudi Journal of Life Sciences
26. Verma, S. K., Das, A. K., Gantait, S., Kumar, V., & Gurel, E. (2019). Applications of carbon nanomaterials in the plant system: a perspective view on the pros and cons. Science of the Total Environment, 667, 485-499.
27. Ghani, U., Naeem, M. Bukhari, S.S.H., Yar, G., Tariq, I., Siddique, S., Nawaz, H.A., Pal, Z.A.A., Nasim, F. and Bukhari, S.A.H. (2019). Prevalence and Risk Factors associated with Hepatitis B and Hepatitis C and their Correlation with Inflammatory Markers among Southern Region of Punjab. Biological Forum - An International Journal, 11(2): 136-143.
28. Muhammad Naeem, Umair Rasool Azmi,Sarmad Ahmad Qamar, Ahmad Munir, Tariq Mahmood, Muhammad Adeel Faryad. 2019. Reliable vaccine production by using Risk Based Bioengineering Strategies. 6th International Conference on "Sustainable Agriculture in Changing Climate: Strategies and Management. 261.
29. Rafeeq, H., Arshad, M. A., Amjad, S. F., Ullah, M. H., Muhammad, H., Imran, R. K., ... & Ajmal, H. Effect of Nickel on Different Physiological Parameters of Raphanus Sativus.
30. Vasilenko, V. N., Frolova, L. N., Mikhailova, N. A., Dragan, I. V., & Tarkaeva, D. A. (2019). Resource-Saving Press for Oil Extrusion from Plant Sources. Russian Engineering Research, 39(7), 575-576.
31. Ghani U, Naeem M, Bukhari SS, Yar G, Tariq I, Siddique S, Nawaz HA, Pal ZA, Nasim F, Bukhari SA. Prevalence and Risk Factors Associated with Hepatitis B and Hepatitis C and their Correlation with Inflammatory Markers among Southern Region of Punjab. (2019). Prevalence and Risk Factors associated with Hepatitis B and Hepatitis C and their Correlation with Inflammatory Markers among Southern Region of Punjab. Biological Forum - An International Journal, 11(2): 136-143
32. Usman Ghani, Muhammad Naeem.2019. Safety assessment of immune mediated reaction to Novel Food Proteins. 6th International Conference on "Sustainable Agriculture in Changing Climate: Strategies and Management. 282
33. Muhammad Naeem Ahmad Munir, Shabaz Shafiq. 2019. The Role of Microbes in coffee Fermentation

and Their impact on Coffee Quality. 1st international Conference on Sustainable Agriculture: Food Security under Changing Climate Scenarios. 56

34. Sandeep, G., Vijayalatha, K. R., & Anitha, T. (2019). Heavy metals and its impact in vegetable crops. International Journal of Chemical Studies, 7(1), 1612-1621.
35. Raj, D., & Maiti, S. K. (2019). Sources, toxicity, and remediation of mercury: an essence review. Environmental monitoring and assessment, 191(9), 1-22.
36. Muhammad Naeem Jabir Ali, Ahmad Munir.2019. Phenolic compounds as a Benchmark for Food Quality. 1st international Conference on Sustainable Agriculture: Food Security under Changing Climate Scenarios. 56.
37. Ahmed Munir, Jabir Ali, Muhammad Naeem. Improvement of Fruit and Vegetable quality through Postharvest Biology. 2019. 1st international Conference on Sustainable Agriculture: Food Security under Changing Climate Scenarios.61
38. Muhammad Adeel, Shahbaz Shafiq, Muhammad Naeem, Ihtisham Ali baber, Muhammad Ali, Rashid Iqbal. 2019. Interactive effect of ascorbic acid and melatonin on morphophyiological and ionic attributes of Okra challenged with salt stress. 1st international Conference on Sustainable Agriculture: Food Security under Changing Climate Scenarios.50
39. Syed Naeem Sajid, Arzoo Rubab, Nadia Azhar, Muhammad Naeem. 2019. Global Environmental Risks Factors and Non Communicable Diseases. International Conference on Innovative Biological and Public Health Research.78
40. Muhammad Naeem, Ahmad Munir, Sadam Hussain Siddiqi. 2019. Development and use of Molecular Markers in Health Care. International Conference on Innovative Biological and Public Health Research.76
41. Ahmad Munir, Muhammad Naeem. 2019. Zika Virus Vaccine Development and New Challenges. International Conference on Innovative Biological and Public Health Research. 47
42. Jabir Ali, Muhammad Naeem. 2019. Emergence of Mosquito Borne Viral diseases in Pakistan. International Conference on Innovative Biological and Public Health Research.47
43. Iqra, Muhammad Naeem, Ahmad Munir. 2019. Novel Approach towards vaccine development though Nanoparticles. International Conference on Innovative Biological and Public Health Research.94
44. Zhang, C., Chen, Y., Xu, W., Chi, S., Li, T., Li, Y., ... & Feng, D. (2019). Resistance of alfalfa and Indian mustard to Cd and the correlation of plant Cd uptake and soil Cd form. Environmental Science and Pollution Research, 26(14), 13804-13811.
45. Muhammad Naeem, Umair Rasool Azmi, Muhammad Irfan, Usman Ghani. 2019. Reducing Risks to Food security from climate change. First International Conference on Sustainable Agriculture: Food Security under Changing Climate Scenarios.79
46. Muhammad Shakir, Humera Razzaq, Lal Hussain Akhtar, Qasim Farooq, Hina Saleem, Aisha Sodagar, Tooba Zafar. (2020). Correlation co-efficient and Path co-efficient analyses for grain yield and its related traits in guar (Cyamopsis tetragonoloba L.) American Based Research Journal 9(11): 1-8.
47. Muhammad Shakir, Hafeez Ahmad Sadaqat, Qasim Farooq, Muzamil Shabir, Aisha Sodagar, Mubashar Nadeem, Tooba Zafar, Aman Ullah, Faiza Rafiq, Rida Anwar, Azka Rizwi, Safa Amjad, Areeba Sajida, Mushaim Iqbal. (2020). A Review on Guar (Cyamopsis tetragonoloba L.): A Cash Crop. International Research Journal of Pharmacy, 11(4): 1-7.
48. Qasim Farooq, Muhammad Shakir, Farial Ejaz, Tooba Zafar, Kinat Durani and Azmat Ullah. 2020. Role of DNA Barcoding in Plant Biodiversity Conservation. Scholars International Journal of Biochemistry, 3(3): 48-52.
49. Aisha Sodagar , Muhammad Ahsan Iqbal, Sadar Uddin Siddiqui, Qasim Farooq, Muhammad Shakir, Asha Mushtaq. (2020). Correlation coefficient and path coefficient analysis for yield and its component traits in common bean (Phaseolus vulgaris L.) germplasm. International Journal of Scientific and Engineering Research 11(12): 181-186.
50. Faisal Mehmood, Nelofar Ansari, Muhammad Shakir, Qasim Farooq, Tooba Zafar, Kinza Shahid, Haiqa Masoud, Qurat ul Ain, Sania Riasat. (2020). Novel approach towards advanced tools in biosciences and their applications. Journal of Biodiversity and Environmental Sciences (JBES), 17(2): 15-21.
51. Umair Rasool Azmi, Hamza Ahmad Qureshi, M.Waseem Akram, M.Naeem, M.irfan, Arslan Ali. 2019. Potassium influence crop yield and quality production . First International Conference on Sustainable Agriculture: Food Security under Changing Climate Scenarios.73
52. Muhammad Naeem. 2019.Principles of Biochemistry & Biological Sciences. Nishtar Publications. First Volume. 464
53. Zaid, A., Mohammad, F., Wani, S. H., & Siddique, K. M. (2019). Salicylic acid enhances nickel stress tolerance by up-regulating antioxidant defense and glyoxalase systems in mustard plants. Ecotoxicology and environmental safety, 180, 575-587.

54. Guo, D., Ren, C., Ali, A., Du, J., Zhang, Z., Li, R., & Zhang, Z. (2019). Streptomyces pactum and sulfur mediated the antioxidant enzymes in plant and phytoextraction of potentially toxic elements from a smelter-contaminated soils. Environmental pollution, 251, 37-44.
55. Al-Layla, N. M., Altamer, D. H., & Sedeeq, S. H. (2019). Biodiesel production from wild mustard (Brassica Juncea L.) seed oil through co-solvent method at room temperature. International Journal of Innovative Technology and Exploring Engineering, 8(4S2), 83-87.
56. Kutschera, A., Dawid, C., Gisch, N., Schmid, C., Raasch, L., Gerster, T., ... & Ranf, S. (2019). Bacterial medium-chain 3-hydroxy fatty acid metabolites trigger immunity in Arabidopsis plants. Science, 364(6436), 178-181.
57. Bukhari, S. A. B. H., Akhtar, M. W., Rehman, S. U., Akhtar, W., Rafeeq, H., Ashraf, A., ... & Aslam, N. (2020). A Novel Approach towards the Identification of plant genes, Bioinformatics Analysis and Role of EIN3 and EIL1 in plants.
58. Raza, A., Iqra, U., Azhar, N., Hussain, I., Khan, M. U., Bano, S., ... & Wahab, A. (2019). Characterization of Selected Plants Leaves with Particular Emphasizes on Epidermis. Haya Saudi Journal of Life Sciences, 4(9), 326-330.