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Evaluation of *Lathyrus* germplasm for yield, quality and drought tolerance

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Abstract
Grass pea (*Lathyrus sativus*) represents a promising legume crop for resource-limited farmers due to its resilience against various environmental stresses. It is valued for its high protein content and unique nutritional profile, including being the sole known dietary source of L-homoarginine. However, its cultivation remains constrained compared to other pulse crops due to the neurotoxic amino acid β-N-oxalyl-L-α, β-diaminopropionic acid (β-ODAP), which can induce neurolathyrism upon excessive consumption of seeds and green tissues. The objective was to screen these accessions for traits crucial to breeding programs like low ODAP content, high yield potential, and drought tolerance. The present investigation on grasspea carried out at Instructional cum Research Farm, Department of Genetics and Plant Breeding, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G) during *rabi season* to screen 89 germplasm/accessions along with check Prateek for low ODAP, high yield and drought tolerance. Screening of genotypes revealed that sufficient amount of variability was present for ODAP content, yield and drought tolerance. 20 most drought tolerant, low ODAP and high yielding genotypes were selected which should be used in future breeding programme.

Keywords: Grass pea, evaluation, ODAP, yield, drought

Introduction
Grasspea (*Lathyrus sativus*), an annual cool-season legume crop belonging to the Fabaceae family, is popular for its resilience and versatility in agricultural systems worldwide (Tripathi *et al*. 2022) [21]. This crop serves multiple purposes, including as animal feed (Parsa *et al*. 2023) [13], a source of human nutrition, and even for bioethanol production (Tesfaw *et al*. 2021) [19]. Its robustness is evident in its ability to endure harsh environmental conditions such as severe drought, waterlogging, heat, salinity, and resistance to various pests and diseases (Lambein *et al*. 2019) [11]. One of the distinguishing features of grasspea is its efficient nitrogen-fixing capability, which can reach up to 124 kg/ha, making it highly beneficial in low-input farming systems (Schulz *et al*. 1999) [18]. Moreover, grasspea stands out as an economical source of protein, essential in the diets of millions of vegetarian populations globally. Its protein content ranges from 17.7% to 49.3%, surpassing that of other legumes like dry pea, faba bean, and lupine (Pastor-Cavada *et al*. 2011; Rizvi *et al*. 2016) [14, 15]. Despite its nutritional benefits and agricultural utility, grasspea has been hindered by the presence of a neurotoxic compound, β-N-oxalyl-Lα, β-diaminopropionic acid (β-ODAP), in its seedlings and seeds. This compound is associated with neurolathyrism, limiting the crop's widespread cultivation and utilization (Rizvi *et al*. 2016; Lambein *et al*. 2019) [15, 11]. Grass pea (*Lathyrus sativus*) represents a promising agricultural crop for both human and animal consumption, while also serving as a valuable subject for research into plant drought resilience (Choudhary *et al*. 2016) [4]. As global water resources become increasingly scarce, understanding the mechanisms that confer drought resistance in grass pea is crucial for developing resilient crop varieties. Drought, as a major abiotic stress, significantly impacts plant growth, development, and overall productivity (Kumar *et al*. 2023) [9].
The path to achieving genotypes with high seed yield, low toxicity, and robust drought tolerance lies in meticulous selection and hybridization processes (Kumari *et al*. 2024) [10].

To pursue this path effectively, a comprehensive understanding of the genetic diversity and resources within *Lathyrus* germplasm is imperative. Therefore, this study was undertaken with the primary objective of evaluating 89 grass pea accessions. The evaluation focused on key traits such as yield potential, toxin content (specifically β-N-oxalyl-L-α, β-diaminopropionic acid or β-ODAP), and drought tolerance. By identifying and characterizing accessions that exhibit superior performance in these areas, this research aims to contribute to the development of improved grass pea varieties. These efforts are essential for enhancing agricultural sustainability, ensuring food security, and mitigating the risks associated with β-ODAP while harnessing the crop's potential in diverse agricultural systems.

Materials and Methods

The Present experiment *i.e.* evaluation of accessions drawn from germplasm of AICRP MULLaRP selected from core of high yield, low ODAP and other characters recorded in catalogue published by (Pandey *et al*. 2008) [12]. The selected 89 accessions and one check variety Prateek were evaluated during *rabi* in a Randomized Completely Block Design (RBD) in two replication of six blocks. Each genotype was grown in a row of 2 meter length keeping row to row distance was 30 cm and 10 cm between plants. All the recommended package of practices was adopted to raise healthy crops.

The observations recorded on five plants in each replication on eight characters viz., leaf area, relative water content (Barrs and Weatherley, 1962) [2], leaf rolling, biomass of 30days old plant, length of 30 days old plant, length of 60 days old plant, seed ODAP content (Briggs *et al*. (1983) [3] and harvest index.

Results and Discussion

Screening of genotypes for low ODAP and high yield

From all the 89 selected accessions along with check the top 20 ranking of low ODAP and high yield is shown in (Table 1).

Table 1: 20 top ranking of accessions/ genotypes for ODAP (low) and yield (high) in grasspea

Rank	Accession number	ODAP Content (%)	Rank	Accession number	Harvest index (%)
1	Prateek (C)	0.071	1	RLK-1042	49.91
2	RLK-207	0.185	2	RLK-581	48.12
3	RLK-626	0.187	3	RLK-30	47.96
4	RLK-46	0.191	4	RLK-24	47.79
5	RLK-169	0.196	5	RLK-9	47.62
6	RLK-629	0.196	6	RLK-513	47.30
7	RLK-180	0.198	7	RLK-1024	46.98
8	RLK-40	0.199	8	RLK-1023	46.50
9	RLK-1042	0.203	9	RLK-454	46.39
10	RLK-423	0.209	10	RLK-628	46.36
11	RLK-149	0.211	11	RLK-29	46.31
12	RLK-345	0.211	12	RLK-580	46.06
13	RLK-1105	0.211	13	RLK-83	46.00
14	RLK-629	0.213	14	RLK-345	45.20
15	RLK-962	0.214	15	RLK-150	45.00
16	RLK-628	0.217	16	RLK-169	45.00
17	RLK-745	0.223	17	RLK-597	44.81
18	RLK-203	0.224	18	Prateek	44.76
19	RLK-331	0.226	19	RLK-962	44.19
20	RLK-321	0.229	20	RLK-78	43.97

In the evaluation of grasspea accessions for low ODAP content and high yield, Prateek (C) stands out with the lowest ODAP content at 0.071%. This is followed by RLK-207 (0.185%) and RLK-626 (0.187%), indicating their potential for safer consumption. RLK-46, RLK-169, and RLK-629 share close ODAP values of 0.191% and 0.196% respectively, making them suitable for breeding programs focused on low neurotoxin levels. For yield, measured by harvest index, RLK-1042 leads with an impressive 49.91%, showcasing its high productivity potential. RLK-581 and RLK-30 follow with 48.12% and 47.96%, respectively. RLK-24 (47.79%) and RLK-9 (47.62%) also demonstrate significant yield potential. Other notable accessions include RLK-513 (47.30%) and RLK-1024 (46.98%), indicating their robustness in yield. Interestingly, RLK-962, while having a relatively low ODAP content of 0.214%, also shows a commendable harvest index of 44.19%, reflecting its balanced profile for both safety and productivity. Prateek also performs well in yield with a harvest index of 44.76%, reaffirming its status as a check variety. Overall, these rankings highlight RLK-1042, RLK-581, and RLK-30 as top contenders for high yield, while Prateek, RLK-207, and RLK-626 are crucial for low ODAP content. Grela *et al*. (2010, 12) [5, 6] also described the significant variability of Lathyrus germplasm for yield and quality traits. Tikariha, (2012) [20] reported a wide range of variability for ODAP in Lathyrus germplasm. Upadhyaya *et al*. (2011) [22] evaluated germplasm for morpho-agronomic, genotypic and quality traits to identify the best representatives.

Screening of genotypes for drought tolerance

The observation on various drought tolerant traits *viz*., leaf area, relative water content, biomass of 30 days old plant, length of 30 days old plant and length of 60 days old plant were recorded and based on performance top 20 ranking accession were identified (Table 2).

Table 2: Top 20 ranking out of 89 accessions (Acc) germplasm for drought tolerance traits in grasspea

Rank	Accn No.	Area cm²	Acc No.	Relative Water Content (%)	Acc No.	Biomass of 30 Days old plant (g)	Acc No.	Length of 30 Days old plant (cm)	Acc No.	Length of 60 days old plant (cm)
1	RLK-310	3.36	RLK-169	88	RLK-962	1.43	RLK-962	23.33	RLK-315	41.66
2	RLK-83	3.34	RLK-81	88	RLK-580	1.43	RLK-592	23.00	RLK-580	40.00
3	RLK-30	3.23	RLK-991	87	RLK-29	1.42	RLK-580	23.00	RLK-310	39.66
4	RLK-51	3.21	RLK-78	86	RLK-51	1.34	RLK-310	23.00	RLK-991	38.66
5	RLK-581	2.79	RLK-962	86	RLK-78	1.31	RLK-51	22.33	RLK-581	37.66
6	RLK-81	2.65	RLK-345	83	RLK-46	1.29	Prateek	22.00	RLK-962	37.00
7	RLK-150	2.61	RLK-1009	82	RLK-24	1.29	RLK-345	21.67	RLK-51	36.33
8	RLK-78	2.60	RLK-513	82	RLK-9	1.28	RLK-991	21.00	RLK-513	35.66
9	RLK-345	2.58	RLK-296	82	RLK-991	1.26	RLK-581	21.00	Prateek	35.00
10	RLK-46	2.58	RLK-30	82	Prateek	1.23	RLK-169	21.00	RLK-30	35.00
11	RLK-962	2.57	RLK-150	81	RLK-47	1.21	RLK-29	20.67	RLK-1259	35.00
12	RLK-513	2.56	Prateek	81	RLK-40	1.18	RLK-46	20.67	RLK-46	34.00
13	RLK-29	2.55	RLK-9	80	RLK-81	1.18	RLK-296	20.67	RLK-251	34.00
14	RLK-169	2.54	RLK-29	80	RLK-150	1.18	RLK-745	20.67	RLK-149	33.33
15	RLK-296	2.43	RLK-51	80	RLK-345	1.18	RLK-513	20.64	RLK-296	33.33
16	RLK-9	2.40	RLK-580	80	RLK-1022	1.17	RLK-9	20.33	RLK-83	33.00
17	RLK-85	2.39	RLK-581	80	RLK-1019	1.13	RLK-78	20.33	RLK-345	33.00
18	RLK-991	2.35	RLK-46	79	RLK-296	1.12	RLK-82	20.33	RLK-24	33.00
19	RLK-24	2.35	RLK-83	79	RLK-1009	1.09	RLK-150	20.33	RLK-29	33.00
20	RLK-116	2.28	RLK-1105	79	RLK-30	1.06	RLK-83	20.00	RLK-40	32.33

The table 2 presents a comprehensive analysis of various plant accessions ranked across five different parameters: leaf area, relative water content, biomass of 30-day-old plants, length of 30-day-old plants, and length of 60-day-old plants. This detailed data allows for an insightful comparison of the growth characteristics and physiological attributes of these accessions. Starting with the leaf area, the accession RLK-310 leads with a maximum area of 3.36 cm², closely followed by RLK-83 at 3.34 cm² and RLK-30 at 3.23 cm². These accessions demonstrate a larger leaf area, potentially indicating better light capture and photosynthetic capacity. RLK-51 and RLK-581 also exhibit significant leaf areas of 3.21 cm² and 2.79 cm², respectively. These values suggest that these accessions might be particularly advantageous for environments where larger leaf area is beneficial. In terms of relative water content (RWC), which is a crucial indicator of plant water status and drought tolerance, RLK-169 and RLK-81 top the list with an impressive 88%. RLK-991 follows closely with 87%, while RLK-78 and RLK-962 both show 86%. These accessions likely possess superior water retention capabilities, making them potentially more resilient under water stress conditions. When examining the biomass of 30-day-old plants, RLK-962 and RLK-580 share the highest value of 1.43 grams, indicating robust early growth. RLK-29 is close behind with 1.42 grams, and RLK-51 and RLK-78 show slightly lower biomass of 1.34 grams and 1.31 grams, respectively. Higher biomass in the early stages of growth is often correlated with better overall plant vigor and productivity. For the length of 30-day-old plants, RLK-962 again takes the lead with a length of 23.33 cm. RLK-592, RLK-580, and RLK-310 each exhibit a length of 23 cm, showing uniformity in their growth patterns at this stage. RLK-51 measures 22.33 cm, demonstrating that these accessions have a consistent early growth height, which can be crucial for early competitive ability and resource acquisition. Finally, looking at the length of 60-day-old plants, RLK-315 is the tallest, reaching 41.66 cm, which suggests excellent growth performance over a more extended period. RLK-580 follows with 40 cm, and RLK-310 with 39.66 cm, indicating sustained growth capabilities. RLK-991 and RLK-581 also maintain significant heights of 38.66 cm and 37.66 cm, respectively, reinforcing their potential for continued growth and development. Overall, the accessions RLK-962, RLK-580, and RLK-310 consistently perform well across multiple parameters, indicating a balanced growth and resilience profile. RLK-962 stands out with top rankings in biomass and early plant length, coupled with high RWC and substantial leaf area. Similarly, RLK-580 demonstrates strong performance in biomass and plant length at both 30 and 60 days, with decent leaf area and RWC. RLK-310 excels in leaf area and maintains significant plant lengths at both stages. These findings underscore the importance of selecting plant accessions that not only perform well in individual parameters but also exhibit balanced and sustained growth across various physiological metrics. Such accessions are likely to be more adaptable and productive in diverse environmental conditions. The data provided can guide researchers and agronomists in selecting and breeding plants with optimal growth characteristics for improved agricultural productivity and resilience. Aloui *et al*. (2023) [1] also reported the effect of stress on relative leaf water content (RLWC) and Leaf area development in grass pea.

Top 20 + 1 ranking germplasm accessions along with check of grasspea for low ODAP, high yield and drought tolerance.

An overall observations of 89 germplasm accessions along with check revealed that accession number RLK- 962 has ranked first followed by accessions RLK-310, RLK-991 RLK-580 RLK-51,RLK-345,Prateek, RLK-30, RLK-581, RLK-46, RLK-150, RLK-169, RLK-513, RLK-9, RLK-29, RLK-78, RLK-83, RLK-296 RLK-24, RLK-81 and RLK-40 (Table 3) on the basis of low ODAP, high yield, more leaf area, high RWC, more biomass at 30 days old plant, high length of 30 days and 60 days old plant. All the 21 genotypes have no leaf roll characteristics indicating drought tolerance traits and hence they can be grouped as drought tolerant genotypes for future use in crop improvement programme.

Table 3: Top 20 + 1 ranking of accessions/ germplasm along with check (Prateek) for ODAP (Low), yield (High) and drought tolerance in in grasspea

Rank	Accession No.	Leaf Area (cm^2)	Relative Water Content (%)	Biomass of 30 Days old plant (g)	Length of 30 Days old plant (cm)	Length of 60 days old plant (cm)	ODAP Content (%)	Harvest index (%)
1	RLK-962	2.57	86	1.43	23.33	37.00	0.214	44.19
2	RLK-310	3.36	78	1.21	23.00	39.66	0.311	46.39
3	RLK-991	2.35	87	1.26	21.00	38.66	0.236	46.36
4	RLK-580	2.23	80	1.43	23.00	40.00	0.301	46.06
5	RLK-51	3.21	80	1.34	23.33	36.33	0.261	40.09
6	RLK-345	2.58	83	1.18	21.67	33.00	0.211	45.20
7	Prateek	2.14	81	1.23	22.00	35.00	0.071	44.76
8	RLK-30	3.23	82	1.06	20.00	35.00	0.323	47.96
9	RLK-581	2.79	80	1.04	21.00	37.66	0.362	48.12
10	RLK-46	2.58	79	1.29	20.67	34.00	0.191	41.95
11	RLK-150	2.61	81	1.18	20.33	33.33	0.232	45.00
12	RLK-169	2.54	88	1.01	21.00	32.33	0.196	45.00
13	RLK-513	2.56	82	1.03	20.64	35.66	0.276	47.30
14	RLK-9	2.05	80	1.28	20.33	25.00	0.229	47.62
15	RLK-29	2.55	80	1.42	20.67	33.00	0.335	46.31
16	RLK-78	2.60	86	1.31	20.33	32.33	0.287	43.97
17	RLK-83	3.34	79	1.09	20.00	33.00	0.269	46.00
18	RLK-296	2.43	82	1.12	20.67	33.33	0.234	42.87
19	RLK-24	2.35	80	1.29	19.12	33.00	0.344	47.79
20	RLK-81	2.65	88	1.18	20.33	32.33	0.347	43.34
21	RLK-40	2.17	78	1.18	19.83	32.33	0.199	43.40

The top-ranking grasspea accession, RLK-962, excels with a biomass of 1.43 g for 30-day-old plants, a plant length of 23.33 cm at 30 days, and 37 cm at 60 days, along with a relative water content of 86% and low ODAP content of 0.214%. RLK-310 follows, featuring the highest leaf area (3.36 cm^2), significant plant lengths, and a high harvest index (46.39%). RLK-991 ranks third, with a notable biomass, relative water content of 87%, and an ODAP content of 0.236%. RLK-580 and RLK-51 also stand out, demonstrating strong growth metrics and yield potential. Prateek serves as an essential check with the lowest ODAP content (0.071%) and a competitive harvest index (44.76%). RLK-345, RLK-150, and RLK-513 balance good biomass, water content, and ODAP levels, indicating their suitability for drought conditions. Other notable accessions like RLK-30, RLK-581, and RLK-46 offer strong yield characteristics and moderate ODAP levels, making them valuable for breeding programs. These rankings highlight the best-performing grasspea varieties for yield, drought tolerance, and low ODAP content, essential for improving crop performance and safety. Drought conditions cause significant reductions in leaf area development and accelerate the extent of leaf senescence (Sarkar *et al*. 2019) [17]. Higher dry weight accumulation in plants is a desirable feature under water deficit conditions (Jaleel *et al*. 2009) [7] and has been correlated with tolerance to drought (Sakthivelu *et al.* 2008) [16]. Moreover, Kage *et al.* (2004) [8] demonstrated that dry matter partitioning and biomass is strongly connected with plant productivity under drought stress conditions.

Conclusion

Screening of genotypes for low ODAP, high yield and drought were carried out for eight characters *viz*., ODAP content, harvest index, leaf area, relative water content, biomass of 30 days old plant, length of 30 days old plant, length of 60 days old plant and leaf roll. The findings revealed that, sufficient amount of variability is present for carrying out various analyses. The 20 most drought tolerant genotypes are selected are RLK-962, RLK-345, RLK-991, RLK-169, RLK-46, RLK-150, RLK-9, RLK-310, RLK-40, RLK-296, RLK-580, RLK-83, RLK-513, RLK-30, RLK-51, RLK-78, RLK-581, RLK-29, RLK-81 and RLK-24. Finding of our study deliver a technology to lowering the ODAP content and improving the protein content in grasspea that can be further utilized in improvement programme to enhance the nutritional quality. The genotypes used in the present study hold promise for future breeding initiatives aimed at developing climate resilient improved grass pea varieties. By harnessing this genetic diversity, efforts can be directed towards enhancing the crop's productivity and nutritional safety, thereby contributing to sustainable agriculture and food security in diverse agro-ecological settings.

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