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Study of Path Analysis and Genetic Divergence in Some Lathyrus Genotypes in Terai Region of West Bengal

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ABSTRACT

The experiments were conducted at Research cum Instructional Farm Uttar Banga Krishi Viswavidyalaya at Pundibari, Coochbehar, West Bengal, India during (2019–20 and 2020–21) for characterization and evaluation according DUS descriptors of physiological characters developed by IPGRI, Rome, Italy. Path analysis and genetic divergence of characters were made where agglomerative or bottom-up approach was made with each observation for finding out the quantitative and qualitative characters association with yield. From the path analysis of the data, days to 50% flowering, days to maturity, plant height, leaf breadth, pods per plant, pod length, pod width, seeds per plant, and seed index were found to have a direct effect on biological yield per plot at 5% and 1% level of significance. Indirect effects of all other characters in these characters were also evaluated. Selection can be done on these parameters for future breeding programme from direct observations. From the dendrogram and cluster analysis, genotypic relatedness among 10 genotypes, three groups of clusters were found. Group-I have five genotypes (Bidhan-1) BK-37-2, Kaikhali Local, Bidhan-2, Pundibari Local, and Alipurduar Local, Group-II has one genotype Berhampur Local, Group-III has four genotypes WBK-10, BK-2, BK-27-1, and BK-7-1. Here Berhampur Local was found to be very distantly related to all the genotypes. Breeding programs or crossing programs between the groups will have better future genotypes because of distantly related genotypes which will ultimately create a broad genetic base in the future lathyrus generation.

KEYWORDS: Cluster analysis, genetic divergence, lathyrus, path analysis

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1. INTRODUCTION

The grass pea [*Lathyrus sativus* (L.)] is a food and fodder crop that belongs to the family Leguminosae (Fabaceae) and subfamily Papilionoideae, tribe Vicieae (=Fabaea) has chromosome number 2n =14. It is also known as Teora in Hindi, Khesari in Bengali, and Kisara in Nepali. Only one species (*Lathyrus sativus* L.) is widely farmed as a food crop (Jackson and Yunus, 1984), whereas other species such as *L. cicera*, *L. clymenum,* and *L. ochrus* are used mostly for fodder. Vavilov (1951) identified two distinct Lathyrus origin centers. The Central Asiatic Centre, which covers northwest India, Afghanistan, Tajikistan, and Uzbekistan, as well as western Tian-Shan, was one of them. The Abyssinian Centre was the second. In addition, Vavilov observed trends in diversity similar to those observed in other pulses such as lentils and broad beans, where smaller-seeded forms were found in southern and southwest Asia, whereas the majority of highly cultivated forms with *Pieris brassicae* seeds and flowers were found throughout the Mediterranean region (Jackson and Yunus 1984).

In north-western Ethiopia, grass pea is the second most important food legume after faba bean (*Vicia faba* L) (Anonymous, 2003).Grass pea is used to be taken as roasted whole seeds, boiled whole seeds, traditional sauce, local drink and the green unripe pods are taken on their way from school to home by local boys in Ethiopia (Fikre et al., 2011). It is the only known dietary source of L-homoarginine. Grass pea is an excellent example of a potential "functional food" (Singh and Rao, 2013; Llorent-Martinez et al., 2017) as a nutraceutical. The amino acid L-homoarginine provides benefits in cardiovascular disease treatments (Rao, 2011; Singh and Rao, 2013; van Wyket al., 2016) and in overcoming the consequences of hypoxia, i.e., the inadequate oxygen supply at the tissue level, associated with cancer tumor development (Ke and Costa, 2006; Jammulama daka et al., 2011). Thus, a daily dietary intake of L-homoarginine through small quantities of grass pea may be valuable for human health and deserves to be studied further (Rao, 2011). One of the physiological functions with possible therapeutic potentials is the activation of protein kinase C, which adds a new dimension to explore its potential in the treatment of Alzheimer's disease, hypoxia, and long-term potentiation of neurons essential for memory (Singh and Rao, 2013). Development of varieties with an improved balance in essential amino acids and diet may be relevant to enhance the nutritional value without jeopardizing the multiple stress tolerance of this promising crop (Lambein, 2019).

Despite their favourable nutritional, agricultural and ecological traits, *lathyrus* species are among the under-recognized legume crops meriting further exploitation as nutrient-rich seeds. The richness of organic acids in *L. sativus* and *L. tingitanus* can override the anti-nutritive effect of phytic acid (Ibrahim et al., 2021). There is great potential for the expansion in the utilization of grass pea in dry areas and zones which are becoming more drought-prone as a result of climate change. However, the crop is unpopular with governments and donors because the plant contains small amounts of a toxin, -b-N-ozalyl-L-a-diaminopropanoic acid (ODAP). Although this toxin can cause irreversible paralysis, known as 'lathyrism', the condition develops in humans only when grass pea is consumed in large quantities, unaccompanied by other foodstuffs (Barrow et al., 1974). ODAP content is polygenically inherited with strong genotype × environment effects on its phenotypic expression (Sharma et al.,1997). Low ODAP content is often associated with undesirable traits such as late flowering and low yield (Kumar et al., 2011). Improvement of grass pea for low toxin content was also done by Kumar et al. (2011) where ODAP content can be decreased without affecting yield and yield-stability of the crop.

Objectives of these investigations were i) to find out the direct and indirect relationship of vegetative, pod and yield characters of lathyrus genotypes with biological yield by path analysis ii) to find out the genetic divergence by cluster analysis of the lathyrus genotypes.

2. MATERIALS AND METHODS

The Study area was in the Uttar Banga Krishi Vishwavidyalaya's "Research cum Instructional Farm" at Pundibari, Cooch-Behar, West Bengal, India during 2019–20 and 2020–21 (total period 10 months). The field is located at 26° 19' 86" N latitude, 89° 23' 53" E longitude, and is 43 m above mean sea level. The experimental site has a sub-Himalayan terai agro-climatic environment. Because of the heavy rainfall, the average annual rainfall is over 3000 mm, with most of it falling between June and September. The temperature begins to climb around the end of February and reaches its peak in July-August, lasting into September.

2.1. Experimental planting material

A total of ten genotypes were used in the study. Seeds are infected with Rhizobium and PSB culture at a rate of 5–7 g kg^{-1} of seed. Planting was done with healthy seeds of all kinds. Three rows of seeds were sown in each allotment. At each site, the row to row and plant to plant distances were kept at 30 cm and 10 cm, respectively. The sowing was done in the second week of November, of both 2019 and 2020. Ten genotypes were collected from local sources. They were collected from different sources of West Bengal (Table 1).

Table 1: Lathyrus genotypes taken for investigation

Sl. No.	Genotypes	Sl. No.	Genotypes
1.	Berhampur local	6.	BK-7-1
2.	WBK-10	7.	Kaikhali local
3.	BK-2	8.	Bidhan-2
4.	BK-27-1	9.	Pundibari local
5.	BK-37-2(Bidhan-1)	10.	Aliporeduar local

2.2. Characters studied

DUS Morphological/Agronomical Characters was developed by International Plant Genetic Resources Institute, Rome, Italy (IPGRI 2000). They were i) Days to 50% flowering, ii) Days to maturity, iii) Branches plant^{-1}, iv) Plant Height, v) Leaf length, vi) Leaf breadth, vii) Pods per plant, viii) Pod length, ix) Pod Width, x) Seeds Pod^{-1}, xi) Seeds plant^{-1}, xii) Seed index (100 seed wt), xiii) Root length, xiv) Biological yield plot^{-1}. Path analysis was done taking 10 genotypes/ varieties of *Lathyrussativus* in 14 different physiological and yield characters. It was done taking genotypic correlation coefficients of all the physiological characters on determinant character biological yield per plot and partitioned into different components on biological yield character to observe the direct and indirect effect of different characters on biological yield parameter. Direct and indirect effects were categorized as per Lenka and Mishra, (1973) method where scales for direct and indirect effects of path analysis:

Value of direct and indirect effects	Rate/scale
0.00 – 0.09	Negligible
0.1 – 0.19	Low
0.2 – 0.29	Moderate
0.3 – 0.99	High
More than 1	Very High

2.3. Cluster analysis

Average linkage clustering was employed in this case. Smaller distances between genotypes were studied and found to form closed groups or clusters, whilst higher gaps between genotypes were found to create distantly related clusters. The distance between the dendogram's points was determined using Euclidean distance. For the Agglomerative approach, the distance was determined using the 'WARD' method, which used variances as a measurement for clustering.

3. RESULTS AND DISCUSSION

3.1. Path analysis

In path analysis, a direct effect on biological yield was found significantly (0.702**) both at 5% and 1% level of significance. Again, according to Lenka and Misra (1973) it was found that moderate indirect effect was found on 50% days to flowering within its correlation (0.27394) which will affect biological yield. Days to 50% flowering was found to have a high effect on pods per plant (0.58253), high effect on pod length (0.95067), very high effect on seeds pod^{-1} (1.14462), seed index (1.24131), moderately high on root length (0.36185) which will affect indirectly on biological yield plant^{-1}. It causes a negative effect on (-0.3016) plant height, leaf length (-0.6933), very high effect on pod width (-1.4266), seeds per plant (-1.6525). Days to 50% flowering affects indirect way positively or negatively via these physiological characters on biological yield (Table 2). The above findings of positive direct effects on seed yield are in accordance with the findings of Pandey et al. (1996), Kour and Agarwal (2016).

3.2. Days to maturity

This character showed a direct positive effect significantly on biological yield (0.542**) both at 5% and 1% level of significance. It means it has a strong positive impact and contribution of its character on the direct effect of biological yield. Although it was found highly negatively (-0.8121) correlated within itself, it means that if days to maturity was found higher, the direct effect on biological yield will be lower and vice versa. Days to maturity was found to have very high effects on plant height (1.01532), seed index (1.08744), and high direct effects on seeds per plant (0.5734) which will have an indirect effect on biological yield. Again, strong and high negative direct effect on branches per plant (-0.2574), pods per plant (-0.2506), seeds per pod (-0.3242), and root length (-0.708). Days to maturity affect indirectly positively or negatively via these physiological characters on biological yield (Table 2).

3.3. Branches plant^{-1}

This character showed a high positive effect on biological yield (0.315) but in a non-significant way. Although this character showed a high direct effect on plant height (0.8901), leaf length (0.39316), pod width (0.77707), seeds plant^{-1} (0.7092), seed index (0.38286), and strongly negative direct effect on days to maturity (-0.411), in its character (-0.5086), pods per plant (-0.4114), pod length (-0.4485) and root length (-0.7382) (Table 2).

3.4. Plant height

Plant height was found to have a very strong positive direct effect on biological yield (0. 946**) both at 5% and 1% levels of significance. Plant height was found a very high positive effect on its character (1.74004), high on pod length (0.9362), very high direct effect on seeds per plant (1.3287), and high direct effect on seed index (0.65574) according to Lenka and Misra (1973). Again, this character was found to have a negative direct effect on days

Table 2: Path Analysis and direct and indirect effects on 14 physiological and yield characters

Characters	DFF	DM	BPP	PH	LL	LB
DFF	0.27394#	0.21827	0.19467	-0.3016	-0.6933	-0.1922
DM	-0.0736	-0.8121#	-0.2574	1.01532	0.19902	-0.0377
BPP	-0.1049	-0.411	-0.5086#	0.8901	0.39316	-0.0537
PH	-0.0475	-0.4739	-0.2602	1.74004#	-0.0607	-0.0501
LL	0.2801	0.23837	0.29494	0.15587	-0.678#	-0.0557
LB	0.38292	-0.2228	-0.1987	0.63403	-0.2743	-0.1375#
PPP	-0.116	-0.1479	-0.1521	1.38298	0.05158	0.04244
PL	0.20929	-0.0679	0.18334	1.30914	-0.5725	-0.0589
PW	0.26354	0.01431	0.26655	0.26965	-0.4764	-0.0773
SPP	-0.3637	-0.3054	-0.0949	0.59953	0.52922	0.08043
SPPL	-0.2488	-0.2559	-0.1982	1.27043	0.2586	0.07981
SI	0.14558	-0.3781	-0.0834	0.48848	-0.1584	-0.0634
RL	-0.0748	-0.4338	-0.2833	1.57786	-0.2665	-0.0471

Table 2: Continue...

Characters	PPP	PL	PW	SPP	SPPL	SI
DFF	0.58253	0.95067	-1.4266	1.14462	-1.6525	1.24131
DM	-0.2506	0.1041	0.02612	-0.3242	0.5734	1.08744
BPP	-0.4114	-0.4485	0.77707	-0.1608	0.7092	0.38286
PH	-1.0938	0.9362	-0.2298	-0.297	1.3287	0.65574
LL	0.10469	1.05063	-1.0419	0.67285	-0.6941	0.5458
LB	0.42464	0.53296	-0.8333	0.50412	-1.056	1.07633
PPP	-1.3762#	0.59741	-0.1675	-0.5034	1.73846	0.67292
PL	-0.6607	1.24435#	-1.3934	0.1438	0.27455	1.29934
PW	-0.1554	1.16925	-1.4829#	0.01591	-0.1748	1.62095
SPP	-0.8035	-0.2076	0.02737	-0.8621#	1.53977	0.14195
SPPL	-1.3146	0.18773	0.14245	-0.7294	1.81986#	0.47723
SI	-0.3965	0.6922	-1.029	-0.0524	0.37181	2.33582#
RL	-1.2933	0.98932	-0.7165	-0.252	1.36323	1.77663

Residual Effect=0 .8392684; #: Direct effect; **: p=0.01; *: p=0.01; DFF: Days to 50% flowering; DM: Days to maturity; BPP: Branches plant^{-1}; PH: Plant Height (cm); LL: Leaf length; LB: Leaf breadth (cm); PPP: Pod plant^{-1}; PL: Pod length (cm); PW: Pod Width (cm); SPP: Seeds Pod^{-1}; SPPL: Seeds Plant^{-1}; SI= 100 seed weight (g); RL: Root length (cm);

to maturity (-0.4739), high on the number of branches per plant (-0.2602), very high on pods per plant (-1.0938), high on pod width (-0.2298), seeds pod^{-1} (-0.297) and very high on root length (-1.2018) according to Lenka and Misra (1973). Plant height has a direct effect on these physiological characters which indirectly affects biological yield per plot via these characters **(**Table 2**).**

3.5. Leaf length

This character was found to have a high positive effect on biological yield in non-significantly (0.353). This character was found to have a direct effect on days to 50% flowering (0.2801), high on days to maturity (0.23837), high on branches per plant (0.29494), very high on pod length (1.05063), high on seeds per pod (0.67285) and high on seed index (0.5458) according to Lenka and Misra (1973). It has a high negative direct effect on its character (-0.678), very high on pod width (-1.0419), and high seeds per plant (-0.6941) **(**Table 2).

3.6. Leaf width

This character was found to have direct positive

significant on biological yield plot^{-1} (0.379*) at a 5% level of significance. This character was found to have a high positive effect on days to 50% flowering (0.38292), very high on plant height (0.63403), pods plant^{-1} (0.42464), high on pod length (0.53296), seeds pod^{-1} (0.50412), seed index (1.0763). It was found to have a high negative effect on (-0.2228), leaf length (-0.2743), very high effect on pod width (-0.8333), very high on seeds plant^{-1} (-1.056), and root length (-0.4534). Leaf width has a direct effect on these physiological characters which indirectly affects biological yield per plot via these characters (Table 2).

3.7. Pods plant^{-1}

This character was found to have a strong positive effect on biological yield (0.777**) at 5% and 1% levels of significance. It was found to have a very high positive direct effect on plant height (1.38298), pod length (0.59741), very high on the number of seeds plant^{-1} (1.73846), and high on seed index (0.67292). It was also found to have a high negative effect on its character (-1.3762), high seeds pod^{-1} (-0.5034), and very high on root length (-1.2455). Pods per plant were found direct effect on these physiological characters negatively or positively which indirectly affects biological yield per plot (Table 2).

3.8. Pod length

This character was found to have a strong high direct effect on biological yield per plot (0.857**) at 5% and 1% level respectively. It was found to have a strong very high positive direct effect on plant height (1.30914), high on pod length (0.59741), very high on its character (1.24435), high seeds plant^{-1} (0.27455), and very high on seed index (1.29934). It was also found to have a strong negative direct effect on leaf length (-0.5725), pods plant^{-1} (0.6607), pod width (-1.3934), and root length (-1.0537) according to Lenka and Misra (1973). It has a direct effect on all of these physiological characters which will have an indirect effect on biological yield per plot via all of these characters (Table 2). Das and Kundagrami (2002) similarly reported in pod length, seed pod^{-1}, 100 seed weight which was recorded positive direct effects on seed yield for two years.

3.9. Pod width

This character was found to have a strong positive direct effect on biological yield per plot (0.613**) at 5% and 1% level of significance. It was found to have a high positive direct effect on pod width (0.26354), branches plant^{-1} (0.26655), plant height (0.26965), very high direct effect on pod length (1.16925), and very high direct effect on seed index (1.62095) according to Lenka and Misra (1973). It was also found to have a high negative effect on leaf length (-.4764), very high on its character (-1.4829), and root length (-0.6403) which will indirectly affect biological yield per plot. So, this character was found to have positive and negative direct effects on these physiological characters and will ultimately indirectly affect biological yield via these characters (Table 2).

3.10. Seeds pod^{-1}

This character was found to have a non-significant negative effect on biological yield (-0.106). It was found to have a strong positive effect on plant height (0.59953), leaf length (0.52922), the high number of seeds plant^{-1} (1.53977). It was also found to have a high negative direct effect on days to 50% flowering (-0.3637), days to maturity (-0.3054), very high pods plant^{-1} (-0.8035), very high on seeds per pod which is own character (-0.8621) and high on root length (-0.3874) according to Lenka and Misra (1973). But all these effects of physiological characters had an insignificant role on biological yield per plot (Table 2).

3.11. Seeds plant^{-1}

This character was found to have a strong positive influence on biological yield per plot (0.496**) at 5% and 1% levels of significance. This character was found to have a strong positive direct effect on plant height (1.27043), leaf length (0.2586) and seed index (0.47723) and seeds plant^{-1} (1.81986) which is its character according to Lenka and Misra (1973). It was also found that it had a strong negative effect on days to 50% flowering (-0.2488), days to maturity (-0.2559), pods plant^{-1} (-1.3146), seeds pod^{-1} (-0.7294), and root length (-0.9928). Sushil kumar et al. (2018) found similar significant results in mutant lines of lathyrus in seeds per plant with seed yield plant^{-1}.

Seeds per plant were found to have direct effects on these characters which will indirectly affect biological yield plot^{-1} via these characters (Table 2).

3.12. Seed index (100 seed wt.)

This character was found to have a strong direct positive effect on biological yield plot^{-1} (0.865**) at 5% and 1% level of significance. It was also found that it had a strong direct positive effect on plant height (0.48848), pod length (0.6922), seeds plant^{-1} (0.37181), and seed index which is own character (2.33582) according to Lenka and Misra (1973). It was also found to have a negative effect on (-0.3781), pods plant^{-1} (-0.3965), pod width (-1.029), and root length (-1.008). This character had direct positive and negative direct effects on physiological characters which will indirectly affect biological yield per plot via these characters (Table 2). Waghmare et al. (1996) reported in their investigation otherwise in the number of pods per plant and but similar in 100-seed weight had large positive and direct effects on seed yield while the remaining characters exhibited direct negative effects on seed yield.

3.13. Root length

This character had a non-significant effect on determinant

character biological yield (1.014). It was also found to have a strong positive effect on plant height (1.57786), pod length (0.98932), seeds plant^{-1} (1.36323), seed index (1.77363), and high negative effects on days to maturity (-0.4338), (-0.2883), leaf length (-0.2665), pods plant^{-1} (-1.2933), pod width (-0.7165) and root (-1.3253) according to Lenka and Misra (1973). But this character was found non-significant effect on biological yield via these physiological characters (Table 2).

3.14. Cluster analysis

Cluster analysis was done was evaluated by adapting agglomerative Hierarchical clustering using the Ward method. In these clusters, three groups of clusters were found (Figure 1).

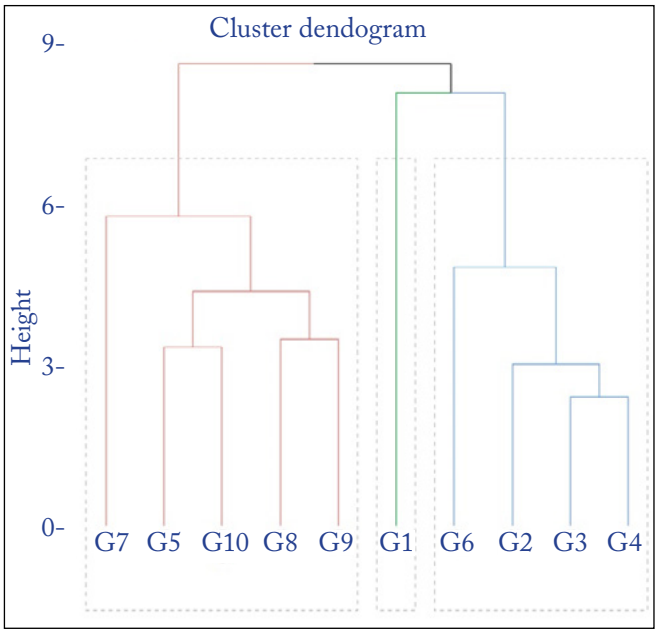

Figure 1: Cluster analysis dendogram of 10 genotypes

Group-I have five genotypes (Bidhan-1) BK-37-2, Kaikhali Local, Bidhan-2, Pundibari Local, and Alipurduar Local. Group-II has one genotype Berhampur Local. Group-III has four genotypes WBK-10, BK-2, BK-27-1, and BK-7-1.

Genotypes were G1- Berhampur Local, G2- WBK-10, G3- BK-2, G4-BK-27-1, G5- Bidhan-1 (Bidhan-37-2), G6- BK-7-1, G7- Kaikhali Local, G8- Bidhan-2, G9- Pundibari Local, and G10 Alipurduar Local (Figure 1).

So, in each group, they are closely related to each other. In Group-I, Bidhan-1 and Alipurduar Local are closely linked, similarly, Bidhan-2 and Pundibari local are closely linked. Again, Kaikhali local was found to be linked with Bidhan1 and Alipurduar Local and Bidhan-2 and Pundibari Local. This Kaikhali Local is distantly related to Group-I and Group-III.

In Group-II, Berhampur Local is distantly related with BK-7-1 which is in Group-III.

In Group-III, BK-2 and BK-27-1 are very closely linked. WBK-10 is closely linked with BK-2 and BK-27-1. BK-7-1 is linked with WBK-10 and closely linked BK-2 and BK-27-1.

Here Berhampur Local was found to be very distantly related to all the genotypes (Figure 1).

4. CONCLUSION

Days to 50% flowering, days to maturity, plant height, leaf breadth, pods per plant, pod length, pod width, seeds per plant and seed index (100 seed wt.) had direct significant effects on biological yield per plot, mass selection can be done. Genetic divergence of some genotypes were found genetically closely linked like (Bidhan-1 and Alipurduar Local), (Bidhan-2 and Pundibari Local) and (BK-2 and BK-27-1). Therefore, any crossing programme should not adopted by a plant breeder between them.

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