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# Correlation and Path Analysis Among Agro-Morphological and Nutritional Composition of White Lupine (Lupinus albus L.)

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## Abstract

White lupin (Lupinus albus L.) is rich in quality protein, reduce malnutrition. This study was conducted to evaluate agro morphological traits in 5x5 simple lattice designs at Holeta Agricultural Research Center during 2018/2019 by using 25 white genotypes. This study was conducted to assess agro-morphological traits with grain yield and to evaluate the genotype correlation coefficient of grain yield to direct and indirect effects through path analysis. Numbers of pod per plant, seed weight per plant and number of seeds per pod at genotypic and phenotypic levels, days to first flowering at the genotypic level and plant height and stem thickness at phenotypic level showed positive and significant correlation with grain yield. While and number of branches per plant, numbers of seed per plant, pod length and pod thickness had negative significant correlation with yield at both levels. These traits had also high to moderate positive indirect effects on grain yield via each other and through other traits at the genotypic level, which suggested simultaneous selection for grain yield. Therefore, the results showed the presence of correlation, direct and indirect effects of traits on grain yield among white lupin was important to select white lupin depend on its agro- morphological and nutritional composition for improvement.

**Keywords:** Correlation: Genotypic and phenotypic Correlation coefficients, path analysis.
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## 1 Introduction

White lupin (*Lupinus albus* L.) is an annual grain legume which belongs to genus *Lupinus* and Leguminosae family. It originated and domesticated in Mediterranean basin (Jansen, 2006). White lupin was cultivated in Greece, Italy, Egypt and Cyprus 2000 years BCE (Clark, 2014). Currently, white lupin mainly cultivated in Northern Europe, Russia, arid Australian plains and Andean highlands of Chile. It is occasionally grown in Africa, including Kenya, Ethiopia, Tanzania, Zimbabwe, South Africa, and Mauritius (Jansen, 2006). Today it is a traditional minor pulse crop, grown around the Mediterranean Black Sea and in the Nile valley, extending to Sudan and Ethiopia. In Ethiopia, it is grown by smallholder farmers in the Amhara and Benishangul Gumuz Regions (Engedaw, 2012).

White lupin seed has 30-40% protein content similar to that of soybean (Jansen, 2006; Laudadio and Tufarelli, 2011). The seed has a higher level of essential amino acids and important dietary minerals (iron and potassium) compared with other legumes such as pea, and faba bean, which are useful as ingredients of functional or healthy food products (Annicchiarico *et al*., 2014). Annual nitrogen fixation by *Lupinus* species is estimated up to 400 kg N/ha/year in Europe and Australia (Jansen, 2006). therefore, it could be used for longer-term rotations (EC, 2013). It produces high above-ground biomass and can be used as green manures (Engedaw, 2012). The crop has deep taproots up to 2 meters which supply the soil with oxygen and water and helps to create a better environment for growth and survival of other plants (Small, 2012).

Lupin production is targeted for its grain used as a snack and for the preparation of local alcoholic drink (*Areke*) and soil fertility maintenance values in Ethiopia though it is largely used as livestock feed in Australia, Europe and America (Yeheyis *et al*., 2010). White lupin is produced by smallholder subsistent farmers in Ethiopia in the main (*Meher*) production season (Yeheyis *et al*., 2010). The Amhara Regional States is the largest producer, and it is produced in Benshangul, Oromiya and South Nation Nationalities People Regional States (SNNPR). The lupin (*Gibto*) produced was 24629.42 tons on 17,877.23 hectares with 1.378 t $ha^{-1}$ average yields in the 2017/18 *Meher* season in Ethiopia. It had a 0.08% share of the total production of pulse crops.

Correlation measures the association between traits that positively or negatively related to yield and each other (Rashad and Sarker 2020) other. The phenotypic correlation is conditioned by the relationship between individual characters and the influence of environmental factors (Hasan *et al*., 2020). The genotypic correlation values higher in magnitude than the corresponding phenotypic correlation coefficient values indicated that association among traits was largely under genetic control and indicated the preponderance of genetic variance in expression of characters (Tsegaye *et al.,* 2012). The correlated response may be caused by pleotropism or linkage disequilibrium. Pleiotropism is the multiplier effects of a single gene (single simultaneously affects several physiological pathways).

Path coefficient analysis indicates the relationship between two traits through their direct and indirect influence of the other characters (Simon *et al.,* 2013). The dependent variable (effect) yield and the independent variables yield components (Azam *et al*., 2014). Path analysis allows more precise clarification of the pattern interaction of other known factors and permits the identification of direct and indirect causes of association and measures the relative importance of each traits (Keles *et al*., 2016). The use of this method is important to come up with meaningful results of cause and effect (Ariyo *et al.,* 2007). Therefore, this study was need for knowledge of the traits having high association and direct or indirect effect on yield that is an important for the improvement of white lupin genotypes with beneficial traits that make major impact on agro-morphological traits.

## 2 Materials and Method

### 2.1. Area of Study

The landraces were evaluated at Holeta (09`N latitude and 38`29E longitude) during 2018/2019. Holeta is located at 2400 meters above sea level and receives 1100 mm of rainfall per annum and a mean relative humidity of 60.6%. Its soil is a predominantly *nitosol* which is characterized by average organic matter (AOM) content of 1.8%, nitrogen 0.17%, phosphorous 4.55 ppm and potassium 1.12 Meq/100 g of soil and pH 5.24 (HARC, 2010).

### 2.2. Experimental design and materials

Twenty-five white lupin landraces collected from northwestern and southern parts of Ethiopia by Ethiopian Biodiversity Institute (EBI) were used in this study. The trial was laid down in a **5 × 5** simple lattice design. Each landrace was planted in one plot in each replication. Each plot was consisting of one row and a total of 12 plants per row or per plot. The spacing between rows and plants was maintained at 0.75 and 0.25 m, respectively. The spacing between blocks and replications was 1.5 m.

### 2.3. Data Collection

Grain yield was collected per plot and later converted to metric tons per hectare. Days to emergence, days to first flowering, days to 50% flowering, days to maturity and 100 seed weight were also determined on a plot basis. Height of lowest primary branch, plant height, petiole length, inflorescence length, number of branches per plant, stem thickness, leaf length, diameter of leaf, verticil number and number of leaflets per leaf, number of pods per plant, pod length, pod thickness, number of seeds per pod, seed length, seed width and seed weight per plant were recorded on plant basis. Protein and mineral composition of grains were estimated on plot basis. Protein content was estimated using kjeldahl method and mineral content were estimated using different method. Phosphorous was estimated by magnesium nitrate dry ash molybdenum blue method as the procedure established by (Murphy and Riley, 1962). Calcium, potassium and iron contents of grain were determined by atomic absorption spectrometry.

### 2.4. Data Analysis

### 2.4.1. Correlation Coefficient

Phenotypic ($r_p$) and genotypic ($r_g$) correlations between two traits were estimated using the formula suggested by Johnson *et al*. (1955) and Singh and Chaudhury (1985).

$$rpxy = \frac{\text{covpxy}}{\sqrt{\sigma^2\text{px}\,.\,\sigma^2 py}} \ldots\ldots\ldots.\ (1)$$

Where;

$rpxy$ = phenotypic correlation coefficient between character x and y
covpxy = phenotypic covariance between character x and y
$\sigma^2$px= phenotypic variance for character x
$\sigma^2 py$ = phenotypic variance for character y

$$rgxy = \frac{covgxy}{\sqrt{\sigma^2 gx.\ \sigma^2 gy}} \ldots\ldots\ldots..(2)$$

Where:

$rgxy$ = genotypic correlation coefficient between character x and y
$covgxy$ = genotypic covariance between character x and y
$\sigma^2 gx$ = genotypic variance for character x
$\sigma^2 gy$ = genotypic variance for character y

The coefficient of correlation at the phenotypic level was tested for significance by comparing the values of correlation coefficient with tabulated r-value at g-2 degree of freedom, where 'g' is a number of genotypes. However, the coefficient of correlations at the genotypic level was tested for significance using the formula (3) described by (Robertson, 1959).

$$\text{t} = \frac{(rgxy)}{SErgxy} \ldots\ldots\ldots..(3)$$

The calculated 't' value was compared with the tabulated 't'' value at the g-2 degree of freedom at a 5% level of significance. Where, g= number of genotypes, $rgxy$ =genotypic correlation coefficient and $SErgxy$ = standard error of genotypic correlation coefficient between character x and y which will be calculated as by below:

$$\mathrm{SE}_{rgxy} = \sqrt{\frac{(1-\mathrm{r}^2)^2}{2H^2x.\ H^2{}_y}} \ldots\ldots\ldots..(4)$$

Where: $\mathrm{SE}_{\mathrm{rgxy}}$=standard error of genotypic correlation coefficient between character x and y, $H^2x$ =Heritability value of character x and
$H^2{}_y$ = heritability value of character y.

### 2.4.2. Path analysis

Based on genotypic and phenotypic correlations, path coefficient analysis which refers to the estimation of direct and indirect effects of the grain yield attributing traits (independent traits) on grain yield (dependent traits) was calculated based on the method used by (Dewey and Lu, 1959) as follows formula:

$$rij = pij + \Sigma rikpkj \ldots\ldots\ldots\ldots (5)$$

Where, $rij$ = mutual association between the independent traits (i) and dependent traits (j) as measured by the genotypic and phenotypic correlation coefficients. $pij$ = direct effects of the independent traits (i) on the dependent variable (j) as measured by the genotypic path coefficients, and $\Sigma rikpkj$ = Summation of components of indirect effects of a given independent traits (i) on a given dependent traits (j) via all other independent traits (k). The residual effect, which determines how best the causal factors account for the variability of the dependent factor yield, was computed using the formula (6);

$$1 = p^2R + \Sigma pijrij \ldots\ldots\ldots\ (6)$$

Where, $p^2R$ is the residual effect and $\Sigma pijrij$is the product of the direct effect of any variable and its correlation coefficient with grain yield.

## 3 Results and Discussion

### 3.1. Correlation coefficient

### 3.1.1. Phenotypic and genotypic correlation of yield with yield component

Phenotypic and genotypic correlation coefficients of grain yield with other traits are presented in (Table 1). Grain yield showed positive and significant correlation with numbers of pod per plant, seed weight per plant, inflorescence length, numbers of seeds per pod and verticil number at phenotypic and genotypic levels while number of branch per plant and pod length at genotypic and pod thickness at phenotypic level had negative significant correlation with grain yield. In agreement with Hibstu (2016) number of pods and number of seeds per plant was highly significant at phenotypic and genotypic correlation with yield at Kessa. Cokkizgin *et al.* (2013) reported number of pods per plant and number of seeds per pod, number of seeds per plant and pod length showed phenotypic and genotypic significant positive correlations among genotypes.

Days to 50% flowering had a positive and significant genotypic correlation with grain yield at genotypic level. Plant height and stem thickness showed positive and significant correlation with grain yield at the phenotypic level. This indicated that except from the number of branches per plant might be common genes that control grain yield and the correlated traits suggested selection of traits simultaneously possible and improving either one or all of these traits could result in high grain yield. Correlations due to genetic causes mainly pleiotropic effects of genes and linkage (phenomenon of genes inherited together) between genes affecting different traits. At the genetic level, positive correlation occurs due to the coupling phase of linkage controlling two different traits. Both types (genotypic and phenotypic) of correlations may also stem from pleiotropy property of gene, which affects two or more traits; as result, it causes simultaneous variations in the two traits when the gene is segregating (Singh, 1993; Falconer *et al.*, 1996; Sharma, 1998).

A number of branches per plant and grain yield showed negative and significant association at the genotypic level, the correlation of the two traits at the phenotypic level was also negative but not significant. More significant genotypic association between the different pairs of traits than the phenotypic correlation means that there is strong association between those traits genetically, but the phenotypic value is lessened by the significant interaction of the environment (Kumar and Reddy, 2016). At the genetic level, negative correlation arises due to the repulsion phase linkage of genes controlling the two traits (Singh, 1993; Falconer *et al.*, 1996). Thus, the selection of landrace for more number of branches per plant might affect the grain yield of white lupin.

Hibstu (2016) observed positive significant correlations of grain yield with inflorescence length and plant height in white lupin genotypes in eastern Ethiopia. Mulgeta *et al.* (2017) report significance and positive correlation between grain yield and plant height in white lupin genotypes evaluated in two locations (Injibara and Debre Tabor). Rubio *et al.* (2004) and Hefny (2013) were reported significance and positive coloration between plant height and day to flowering with grain yield in white lupin genotypes evaluated in Spain. Zerihun (2016) reported that days to flowering and maturity had significant positive phenotypic and genotypic correlations with yield. Georgieva *et al.* (2018) and Cokkizgin *et al.* (2013) also reported that grain yield of lupin genotypes had a significant correlation with most other agro-morphology traits.

### 3.1.2. Phenotypic and genotypic correlations among yield component

Height of lowest primary branch with plant height and pod thickness and plant height with petiole length, number of branches per plant, stem thickness and seed weight per plant had positive and significant phenotypic correlations. Inflorescence length with plant height, petiole length, number of branches per plant, verticil number, seed weight per plant and number of pods per plant, and verticil number with number of branches per plant, number of pods per plant, seed weight per plant, seed weight per plant with petiole length and stem thickness and calcium content of grain showed positive and significant phenotypic correlations. A number of pods per plant with a number of branches per plant, stem thickness and petiole length, and number of seeds with the calcium content of grain showed positive and significant association at the phenotypic level. Whereas at a genotypic level, plant height with a protein content of the grain, number of pods per plant with a number of branches per plant, verticil number, pod length, Seed weight per plant and stem thickness while the number of seeds with the calcium content of grain and verticil number had a positive and significant association.

In addition, phosphorus content of grain showed positive and significant correlation with verticil number and calcium, day to first flowering with day to 50% flowering, number branch per plant and number of seed per plant, number of seed per plant with day to 50% flowering and verticil number, seed weight per plant with petiole length, inflorescence length, verticil number, number of pods per plant and iron with day to maturity at genotypic level (Table 1). The correlation coefficient is a statistical measure that is used to find out the degree of relationship between two or more variables and changes brought about by a natural or artificial selection among correlated traits. This is particularly true among traits that the genotypic correlation coefficient was similar in sign and nature to the corresponding phenotypic correlation coefficient (Singh, 1993; Falconer *et al.*, 1996; Sharma, 1998). In agreement with the current research results, Hibstu (2016) reported a significant correlation between numbers of pods per plant, number of seeds per pod, number of seeds and pod length showed phenotypic and genotypic significant positive correlations among themselves.

Georgieva and Kosev (2016) reported strong positive phenotypic correlations between plant height with stem length and pod length; between seed weight per plant and plant height, a number of pods per plant and pod length. Georgieva *et al.* (2018) Observed highly significant and positive correlations of the seed weight per plant with a number of pods. Height to lowest primary branch with number of branches per plant and verticil number at the phenotypic level and height lowest primary branch with a number of pods per plant at genotypic level had negative and significant correlations. Phosphorus content of grain with plant height at both levels and with the number of branches per plant at phenotypic level showed strong negative associations. Pod thickness with petiole length, inflorescence length and verticil number, and a number of seeds per pod with petiole length had negative and significant phenotypic correlations. similar results by Hibstu (2016) reported that inflorescence length with number of pods per plant, pod thickness with number of pods per plant at phenotypes level in Kessa, 2012**;** petiole length with number of pods per plant and stem thickness, number of pods per plant with plant height at genotypic level and stem thickness with plant height at phenotypes level had significance and negative correlations at Hirna, 2012.

Table 1. Phenotypic (above diagonal) and genotypic (below-diagonal) correlations of among 22 traits of white lupin as evaluated at Holeta, 2018/2019

| Traits | DFE | DFF | D50%F | DM | HLPB | PH | PTL | IFL | NBPP | ST | LL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DFE | | -0.01 | 0.11 | 0.22 | -0.01 | 0.06 | 0.08 | -0.21 | 0.27* | -0.02 | 0.04 |
| DFF | 0.07 | | -0.18 | 0.00 | 0.06 | 0.00 | 0.28 | 0.18 | -0.15 | 0.07 | -0.13 |
| D50%F | $0.39^{*}$ | 0.01 | | 0.14 | -0.11 | 0.02 | 0.11 | 0.00 | 0.07 | 0.11 | -0.02 |
| DM | 0.12 | 0.19 | -0.17 | | -0.18 | -0.08 | -0.06 | -0.08 | 0.18 | 0.07 | -0.09 |
| HLPB | -0.19 | 0.16 | -0.19 | -0.14 | | $0.39^{**}$ | -0.17 | -0.07 | $-0.27^{*}$ | 0.25 | -0.05 |
| PH | 0.05 | 0.20 | 0.23 | -0.17 | 0.14 | | $0.32^{*}$ | $0.58^{***}$ | $0.30^{*}$ | $0.43^{**}$ | -0.02 |
| PTL | 0.23 | 0.36 | 0.30 | 0.19 | -0.35 | 0.12 | | $0.58^{***}$ | 0.20 | 0.06 | -0.23 |
| IFL | -0.20 | 0.15 | 0.15 | 0.12 | -0.19 | 0.29 | 0.30 | | $0.34^{*}$ | 0.25 | 0.06 |
| NBPP | $0.44^{*}$ | -0.37 | 0.22 | 0.07 | $-0.39^{*}$ | 0.20 | 0.18 | 0.23 | | 0.07 | 0.20 |
| ST | -0.32 | 0.02 | 0.19 | 0.02 | -0.07 | 0.24 | -0.04 | 0.00 | -0.02 | | 0.04 |
| LL | -0.04 | -0.30 | 0.09 | 0.02 | -0.01 | 0.07 | -0.22 | 0.30 | $0.45^{*}$ | -0.14 | |
| VN | 0.00 | 0.31 | 0.25 | 0.04 | -0.37 | -0.05 | 0.33 | $0.51^{*}$ | 0.06 | -0.13 | 0.07 |
| NPPP | -0.03 | -0.28 | 0.32 | 0.07 | $-0.62^{**}$ | -0.06 | 0.26 | 0.33 | $0.46^{*}$ | $0.39^{*}$ | 0.21 |
| PL | -0.06 | -0.23 | 0.12 | -0.17 | -0.26 | 0.16 | -0.08 | 0.13 | 0.15 | 0.12 | -0.13 |
| PT | -0.14 | -0.09 | -0.35 | 0.06 | 0.06 | 0.31 | -0.26 | 0.17 | 0.26 | -0.12 | 0.34 |
| NSPP | $0.39^{*}$ | 0.28 | $0.52^{**}$ | -0.04 | -0.09 | -0.07 | 0.16 | 0.16 | 0.17 | -0.01 | 0.01 |
| SWPP | -0.12 | 0.19 | 0.34 | 0.19 | -0.25 | 0.37 | $0.46^{*}$ | $0.76^{***}$ | 0.15 | 0.22 | 0.26 |
| GY | -0.33 | $0.52^{**}$ | 0.07 | 0.18 | -0.06 | 0.26 | 0.19 | $0.52^{**}$ | $-0.42^{*}$ | 0.21 | 0.14 |
| Pr | 0.28 | 0.27 | 0.23 | 0.01 | 0.12 | $0.50^{*}$ | 0.32 | 0.13 | 0.25 | -0.01 | 0.28 |
| P | -0.38 | -0.12 | -0.05 | -0.36 | 0.12 | $-0.40^{*}$ | -0.28 | 0.31 | -0.09 | -0.09 | 0.08 |
| Ca | -0.04 | 0.30 | 0.23 | -0.12 | -0.03 | -0.35 | 0.05 | 0.14 | -0.17 | 0.15 | -0.17 |
| Fe | -0.20 | -0.06 | -0.16 | $0.44^{*}$ | 0.07 | 0.08 | 0.00 | 0.10 | -0.28 | 0.09 | -0.10 |

| Traits | VN | NPPP | PL | PT | NSPP | SWPP | GY | Pr | P | Ca | Fe |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DFE | 0.08 | -0.11 | 0.05 | 0.03 | 0.22 | -0.14 | -0.25 | 0.24 | -0.20 | -0.09 | -0.24 |
| DFF | 0.20 | -0.11 | -0.14 | -0.04 | 0.08 | 0.05 | 0.52 | 0.16 | 0.02 | 0.02 | -0.23 |
| D50%F | 0.00 | 0.17 | -0.15 | $-0.31^{*}$ | $0.40^{*}$ | 0.15 | 0.06 | 0.17 | -0.09 | 0.15 | 0.11 |
| DM | 0.13 | -0.10 | $-0.32^{*}$ | -0.08 | 0.07 | -0.03 | 0.21 | 0.20 | $-0.44^{*}$ | 0.02 | $0.37^{**}$ |
| HLPB | $-0.28^{*}$ | -0.26 | 0.04 | $0.32^{*}$ | -0.16 | 0.17 | -0.05 | -0.15 | 0.00 | 0.12 | -0.16 |
| PH | 0.26 | 0.20 | 0.13 | -0.05 | -0.19 | $0.70^{***}$ | $0.25^{*}$ | 0.08 | $-0.36^{*}$ | 0.17 | 0.00 |
| PTL | 0.19 | 0.25 | -0.04 | $-0.40^{**}$ | 0.17 | $0.43^{***}$ | 0.18 | 0.17 | -0.20 | -0.03 | -0.10 |
| IFL | $0.44^{*}$ | $0.43^{**}$ | 0.04 | $-0.35^{*}$ | 0.03 | $0.68^{***}$ | $0.51^{*}$ | -0.04 | -0.06 | 0.13 | -0.06 |
| NBPP | $0.36^{*}$ | $0.43^{**}$ | 0.06 | -0.08 | 0.01 | 0.26 | 0.86 | 0.13 | $-0.28^{*}$ | 0.06 | 0.03 |
| ST | 0.03 | $0.38^{**}$ | 0.05 | -0.14 | -0.13 | $0.39^{***}$ | $0.22^{*}$ | -0.04 | -0.12 | -0.03 | -0.13 |
| LL | 0.07 | 0.20 | -0.02 | 0.16 | -0.26 | 0.10 | 0.14 | 0.07 | 0.19 | -0.20 | -0.11 |
| VN |  | $0.46^{***}$ | 0.14 | $-0.30^{*}$ | 0.11 | $0.44^{***}$ | $0.40^{**}$ | 0.11 | 0.06 | $0.37^{**}$ | -0.01 |
| NPPP | $0.44^{*}$ |  | $0.3^{*}$ | -0.17 | -0.04 | 0.58 | $0.42^{**}$ | -0.19 | 0.10 | 0.14 | -0.05 |
| PL | 0.28 | $0.43^{*}$ |  | 0.22 | $-0.31^{*}$ | 0.13 | -0.13 | -0.27 | 0.16 | 0.01 | -0.22 |
| PT | -0.06 | -0.05 | 0.07 |  | -0.18 | -0.18 | $-0.05^{**}$ | -0.04 | 0.07 | 0.07 | -0.09 |
| NSPP | $0.48^{*}$ | 0.12 | -0.24 | -0.22 |  | -0.11 | $0.76^{**}$ | 0.10 | 0.18 | $0.29^{*}$ | -0.12 |
| SWPP | $0.51^{***}$ | $0.57^{***}$ | 0.11 | -0.05 | 0.19 |  | $0.80^{**}$ | 0.03 | -0.09 | 0.18 | 0.10 |
| GY | $0.41^{*}$ | $0.29^{**}$ | $-0.15^{**}$ | -0.04 | $0.10^{**}$ | $0.69^{**}$ |  | 0.08 | -0.11 | 0.21 | 0.21 |
| Pr | 0.13 | -0.12 | -0.24 | 0.16 | 0.13 | 0.30 | -0.04 |  | -0.20 | -0.24 | -0.06 |
| P | $0.40^{*}$ | 0.16 | 0.12 | -0.03 | 0.27 | 0.04 | 0.12 | -0.35 |  | -0.05 | -0.20 |
| Ca | 0.55 | 0.15 | -0.03 | -0.15 | $0.72^{**}$ | 0.00 | 0.19 | -0.27 | $0.54^{*}$ |  | 0.02 |
| Fe | -0.28 | -0.19 | -0.06 | 0.14 | -0.34 | 0.07 | -0.25 | -0.11 | -0.28 | -0.30 |  |

*, ** & ***: significant at 5%, 1% and 0.01% level of significant test DFE = Day to 50% emergence, DFF = Days to first flowering, D50%F = day to 50% flowering, DM = day to maturity, HLPB = height lowest primary branch, PH = plant height (cm), PTL = petiole length, IFL = inflorescence length, NBPP = number of branch per plant, ST = stem thickness, LL = leaf length, VN = verticil number, NPPP = number of pod per plant, PL = pod length, PT = pod thickness, NSPP = number of seeds per pod, SWPP = seed weight per plant, GY = grain yield, Pr = protein, P = phosphorus, Ca = calcium, Fe = iron

## 3.2. Path Analysis

### 3.2.1. Genotypic path coefficient analysis of yield with yield component

The results of the landrace path analysis are presented in (Table 2). [25] Rated the direct and indirect effects into negligible (0.00-0.09), low (0.10-0.19), moderate (0.20-0.29), high (0.30-1.00) and very high (> 1.00). Based on these rates, seed weight per plant, numbers of pod per plant, number of seed per pod, protein, calcium contents of grain and number of branches per plant high positive directs effect 0.42, 0.50, 0.51, 0.52 and 65 on yield respectively. Days to first flowering, leaf length and plant height had moderate positive direct effects 0.22, 0.25 and 0.28, respectively. In addition, seed weight per plant through a number of pods per plant, inflorescence length, petiole length and verticil number, protein content of grain via plant height, calcium via number of seed per plant, verticil number and phosphorus content of grain had moderate to high (0.21-0.39) positive indirect effects on grain yield. Thus, the traits with positive direct effects could be used as an indirect selection of genotypes for grain yield. The path analysis is the portioning of the total correlation into direct and indirect effects of the independent variable on the dependent variable (Singh and Chaudhary, 1977; Dabholkar, 1992; Nadarajian and Gunasekaran, 2005).

Petiole length and height lowest primary branch had high and negative direct effects -0.3 and -0.42, respectively, while pod thickness and verticil number had moderate negative direct effects -0.21 and -0.29, respectively. However, the height lowest primary branch via number of pods per plant and number of branches per plant through days to first flowering had 0.25 and 0.24, respectively, moderate indirect effects on grain yield at the genotypic level. Day to 50% flowering had low negative direct effects -0.15 and stem thickness had the direct negative effect -0.19 on grain yield while pod length, phosphorous contents of grain and day to 50% emergency negligible negative direct effect -0.05, -0.08 and -0.09 on yield. Day to maturity, inflorescence length had a low positive direct effect on yield and iron had negligible positive direct effects on yield. If the variable or trait has positive correlation and direct effect of the variable or trait is negative or negligible, the positive correlation of the trait is because of the indirect effects through other traits. In such situation, the indirect causal factors/traits are to be considered simultaneously for selection (Singh and Chaudhary, 1977). Similar results were reported by Hibstu (2016) were day to maturity and number of pods per plant indicates positive direct effect on yield at Hirna. Tadele *et al.* (2014) Report day to maturity positive direct effect on seed yield. Hibstu (2016) observed that the day to 50% flowering showed a direct negative effect at Kessa and Hirna, respectively. Similar results were reported by Tadele *et al* (2014) and Diriba *et al.* (2014) were days to 50% flowering exerted negative direct effect on seed yield, also reported that days to 50% flowering exerted negative direct effect on yield.

### 3.2.2. Phenotypic path coefficient analysis of yield with yield component

The phenotypic correlation coefficient exhibited between grain yield and other traits indicated the presence of significant association had positive and negative correlation. This implies the importance of partitioning the correlation coefficients into direct and indirect effects on grain yield per hectare to determine the selection for

Grain yield improvement. Seed weight per plant 0.96, positive direct effect with grain yield followed by Number of pod per plant 0.31, number of seed per pod 0.29, leave length 0.18, Day to first flowering and stem thickness 0.17, verniculate numbers 0.16, Iron composition 0.14, calcium composition 0.07 and pod thickness and pod length 0.03. All these traits had positive and significant phenotypic correlation with grain yield. High indirect effect had also positive effect on yield by seed weight per plant via plant height, inflorescence length, Verticil number, pod length, stem thickness and number of branches per plant. This trait had an indirect role for breeding to select genotype for improvement. However, the height of primary lower plant -0.15 and the number of branches per plant -0.30 was negative direct effect on grain yield. All the result direct and indirect effect was shown in (Table 3). The positive direct effects of the traits on yield indicate the presence of an association between the traits and yield so the selection of these traits would be rewarding to improve white lupin yield Singh and Narayanan (1993). The presence study was In agreement with Hibstu (2016) observe positive direct effects for number of seed per pod at Kessa and number of pod per plant at Kessa and Hirna on yield. Similar results were reported by Tadele *et al* (2014) where the number of pods/plants and seeds per pods had very high and positive direct effect on seed yield in one site. Also, Georgieva and Kosev (2016) report that seed weight per plant and the number of seeds per plant were the highest positive direct effects on yield for both cultivars (Garant and Chernilovec). Lopez-Bellido *et al.* (2000) Observe the number of pods per plant was direct effect on grain yield of white lupin.

Table 2. Direct effects (bold diagonals) indirect effects (off-diagonals) of 22 traits on grain yield at genotypic level evaluated at Holeta 2018/2019

| Traits | DFE | DFF | D50%F | DM | HLPB | PH | PTL | IFL | NBPP | ST | LL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DFE | **-0.09** | 0.02 | -0.06 | 0.01 | 0.08 | 0.01 | -0.07 | -0.03 | -0.20 | 0.06 | -0.01 |
| DFF | -0.01 | **0.22** | 0.00 | 0.02 | -0.07 | 0.05 | -0.11 | 0.02 | 0.24 | 0.00 | -0.08 |
| D50%F | -0.03 | 0.00 | **-0.15** | -0.02 | 0.08 | 0.06 | -0.09 | 0.02 | -0.14 | -0.04 | 0.02 |
| DM | -0.01 | 0.04 | 0.03 | **0.11** | 0.06 | -0.05 | -0.06 | 0.02 | -0.04 | 0.00 | 0.00 |
| HLPB | 0.02 | 0.03 | 0.03 | -0.01 | **-0.42** | 0.04 | 0.11 | -0.03 | 0.25 | 0.01 | 0.00 |
| PH | 0.00 | 0.04 | -0.03 | -0.02 | -0.06 | **0.28** | -0.04 | 0.04 | -0.13 | -0.04 | 0.02 |
| PTL | -0.02 | 0.08 | -0.05 | 0.02 | 0.15 | 0.03 | **-0.30** | 0.04 | -0.12 | 0.01 | -0.05 |
| IFL | 0.02 | 0.03 | -0.02 | 0.01 | 0.08 | 0.08 | -0.09 | **0.15** | -0.15 | 0.00 | 0.08 |
| NBPP | -0.04 | -0.08 | -0.03 | 0.01 | 0.16 | 0.06 | -0.05 | 0.03 | **0.65** | 0.00 | 0.11 |
| ST | 0.03 | 0.00 | -0.03 | 0.00 | 0.03 | 0.07 | 0.01 | 0.00 | 0.01 | **-0.19** | -0.04 |
| LL | 0.00 | -0.07 | -0.01 | 0.00 | 0.00 | 0.02 | 0.06 | 0.05 | -0.29 | 0.03 | **0.25** |
| VN | 0.00 | 0.07 | -0.04 | 0.00 | 0.16 | -0.02 | -0.10 | 0.08 | -0.04 | 0.02 | 0.02 |
| NPPP | 0.00 | -0.06 | -0.05 | 0.01 | 0.26 | -0.02 | -0.08 | 0.05 | -0.30 | -0.08 | 0.05 |
| PL | 0.01 | -0.05 | -0.02 | -0.02 | 0.11 | 0.05 | 0.02 | 0.02 | -0.10 | -0.02 | -0.03 |
| PT | 0.01 | -0.02 | 0.05 | 0.01 | -0.03 | 0.09 | 0.08 | 0.02 | -0.17 | 0.02 | 0.09 |
| NSPP | -0.03 | 0.06 | -0.08 | 0.00 | 0.04 | -0.02 | -0.05 | 0.02 | -0.11 | 0.00 | 0.00 |
| SWPP | 0.01 | 0.04 | -0.05 | 0.02 | 0.11 | 0.10 | -0.14 | 0.11 | -0.10 | -0.04 | 0.07 |
| Pr | -0.02 | 0.06 | -0.04 | 0.00 | -0.05 | 0.14 | -0.10 | 0.02 | -0.16 | 0.00 | 0.07 |
| P | 0.03 | -0.03 | 0.01 | -0.04 | -0.05 | -0.11 | 0.09 | 0.05 | 0.06 | 0.02 | 0.02 |
| Ca | 0.00 | 0.07 | -0.03 | -0.01 | 0.01 | -0.10 | -0.01 | 0.02 | 0.11 | -0.03 | -0.04 |
| Fe | 0.02 | -0.01 | 0.02 | 0.05 | -0.02 | 0.02 | 0.00 | 0.01 | 0.18 | -0.02 | -0.03 |

Residual effect = 0.018

Table 2. Continued

| Traits | VN | NPPP | PL | PT | NSPP | SWPP | Pr | P | Ca | Fe | rpY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DFE | 0.00 | 0.00 | 0.00 | 0.03 | -0.06 | -0.06 | 0.12 | 0.03 | -0.02 | -0.01 | -0.25 |
| DFF | -0.09 | -0.04 | 0.01 | 0.02 | -0.04 | 0.10 | 0.11 | 0.01 | 0.16 | 0.00 | 0.52 |
| D50%F | -0.07 | 0.05 | -0.01 | 0.08 | -0.08 | 0.17 | 0.10 | 0.00 | 0.12 | -0.01 | 0.06 |
| DM | -0.01 | 0.01 | 0.01 | -0.01 | 0.01 | 0.10 | 0.00 | 0.03 | -0.06 | 0.03 | 0.21 |
| HLPB | 0.11 | -0.09 | 0.01 | -0.01 | 0.01 | -0.13 | 0.05 | -0.01 | -0.02 | 0.00 | -0.05 |
| PH | 0.02 | -0.01 | -0.01 | -0.07 | 0.01 | 0.19 | 0.21 | 0.03 | -0.18 | 0.00 | $0.25^{*}$ |
| PTL | -0.10 | 0.04 | 0.00 | 0.06 | -0.03 | 0.24 | 0.14 | 0.02 | 0.02 | 0.00 | 0.18 |
| IFL | -0.15 | 0.05 | -0.01 | -0.04 | -0.02 | 0.39 | 0.05 | -0.03 | 0.07 | 0.01 | $0.51^{*}$ |
| NBPP | -0.02 | 0.07 | -0.01 | -0.06 | -0.03 | 0.08 | 0.11 | 0.01 | -0.09 | -0.02 | 0.86 |
| ST | 0.04 | 0.06 | -0.01 | 0.03 | 0.00 | 0.11 | 0.00 | 0.01 | 0.08 | 0.01 | $0.22^{*}$ |
| LL | -0.02 | 0.03 | 0.01 | -0.07 | 0.00 | 0.14 | 0.12 | -0.01 | -0.09 | -0.01 | 0.14 |
| VN | **-0.29** | 0.07 | -0.01 | 0.01 | -0.07 | 0.26 | 0.05 | -0.03 | 0.28 | -0.02 | $0.40^{**}$ |
| NPPP | -0.13 | **0.50** | -0.02 | 0.01 | -0.02 | 0.29 | -0.05 | -0.01 | 0.08 | -0.01 | $0.42^{**}$ |
| PL | -0.08 | 0.07 | **-0.05** | -0.01 | 0.04 | 0.06 | -0.10 | -0.01 | -0.02 | 0.00 | -0.13 |
| PT | 0.02 | -0.01 | 0.00 | **-0.21** | 0.03 | -0.03 | 0.07 | 0.00 | -0.08 | 0.01 | $-0.05^{**}$ |
| NSPP | -0.14 | 0.02 | 0.01 | 0.05 | **0.51** | 0.10 | 0.05 | -0.02 | 0.37 | -0.02 | $0.76^{**}$ |
| SWPP | -0.15 | 0.09 | 0.00 | 0.01 | -0.03 | **0.51** | 0.13 | 0.00 | 0.00 | 0.11 | $0.80^{**}$ |
| Pr | -0.04 | -0.02 | 0.01 | -0.03 | -0.02 | 0.15 | **0.42** | 0.03 | -0.14 | -0.01 | 0.27 |
| P | -0.12 | 0.02 | -0.01 | 0.01 | -0.04 | 0.02 | -0.15 | **-0.08** | 0.28 | -0.02 | -0.04 |
| Ca | -0.16 | 0.02 | 0.00 | 0.03 | -0.11 | 0.00 | -0.11 | -0.04 | **0.52** | -0.02 | 0.12 |
| Fe | 0.08 | -0.03 | 0.00 | -0.03 | 0.05 | 0.03 | -0.05 | 0.02 | -0.16 | **0.06** | 0.19 |

Table 3. Direct effects (bold diagonals) indirect effects (off-diagonals) of 22 traits on grain yield at phenotypic level evaluated at Holeta 2018/2019

| Traits | DFE | DFF | D50%F | DM | HLPB | PH | PTL | IFL | NBPP | ST | LL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DFE | **-0.08** | 0.00 | -0.01 | -0.01 | 0.00 | 0.00 | -0.01 | 0.01 | -0.08 | 0.00 | 0.01 |
| DFF | 0.00 | **0.17** | 0.01 | 0.00 | -0.01 | 0.00 | -0.02 | -0.01 | 0.05 | 0.01 | -0.02 |
| D50%F | -0.01 | -0.03 | **-0.07** | 0.00 | 0.02 | 0.00 | -0.01 | 0.00 | -0.02 | 0.02 | 0.00 |
| DM | -0.02 | 0.00 | -0.01 | **-0.03** | 0.03 | 0.00 | 0.00 | 0.00 | -0.05 | 0.01 | -0.02 |
| HLPB | 0.00 | 0.01 | 0.01 | 0.01 | **-0.15** | -0.01 | 0.01 | 0.00 | 0.08 | 0.04 | -0.01 |
| PH | 0.00 | 0.00 | 0.00 | 0.00 | -0.06 | **-0.02** | -0.02 | -0.02 | -0.09 | 0.07 | 0.00 |
| PTL | -0.01 | 0.04 | -0.01 | 0.00 | 0.02 | -0.01 | **-0.07** | -0.02 | -0.06 | 0.01 | -0.04 |
| IFL | 0.02 | 0.03 | 0.00 | 0.00 | 0.01 | -0.01 | -0.04 | **-0.03** | -0.10 | 0.04 | 0.01 |
| NBPP | -0.02 | -0.03 | 0.00 | 0.00 | 0.04 | -0.01 | -0.01 | -0.01 | **-0.30** | 0.01 | 0.04 |
| ST | 0.00 | 0.01 | -0.01 | 0.00 | -0.04 | -0.01 | 0.00 | -0.01 | -0.02 | **0.17** | 0.01 |
| LL | 0.00 | -0.02 | 0.00 | 0.00 | 0.01 | 0.00 | 0.02 | 0.00 | -0.06 | 0.01 | **0.18** |
| VN | 0.01 | 0.04 | 0.00 | 0.00 | 0.04 | -0.01 | -0.01 | -0.01 | -0.11 | 0.00 | 0.01 |
| NPPP | 0.01 | 0.02 | 0.01 | 0.00 | 0.04 | 0.00 | 0.02 | 0.01 | 0.13 | 0.07 | 0.04 |
| PL | 0.00 | -0.02 | 0.01 | 0.01 | -0.01 | 0.00 | 0.00 | 0.00 | -0.02 | 0.01 | 0.00 |
| PT | 0.00 | -0.01 | 0.02 | 0.00 | -0.05 | 0.00 | 0.03 | 0.01 | 0.02 | -0.02 | 0.03 |
| NSPP | -0.02 | 0.01 | -0.03 | 0.00 | 0.02 | 0.00 | -0.01 | 0.00 | 0.00 | -0.02 | -0.05 |
| SWPP | 0.01 | 0.01 | -0.01 | 0.00 | -0.03 | -0.02 | -0.03 | -0.02 | -0.08 | 0.07 | 0.02 |
| Pr | -0.02 | 0.03 | -0.01 | -0.01 | 0.02 | 0.00 | -0.01 | 0.00 | -0.04 | -0.01 | 0.01 |
| P | 0.02 | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 | 0.00 | 0.08 | -0.02 | 0.03 |
| Ca | 0.01 | 0.00 | -0.01 | 0.00 | -0.02 | 0.00 | 0.00 | 0.00 | -0.02 | -0.01 | -0.04 |
| Fe | 0.02 | -0.04 | -0.01 | -0.01 | 0.02 | 0.00 | 0.01 | 0.00 | -0.01 | -0.02 | -0.02 |

Residual effect=0.11

Table 3. Continued

| Traits | VN | NPPP | PL | PT | NSPP | SWPP | Pr | P | Ca | Fe | rpY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DFE | 0.01 | 0.03 | 0.00 | 0.00 | 0.02 | -0.13 | 0.00 | 0.03 | -0.01 | -0.03 | -0.25 |
| DFF | 0.03 | 0.03 | 0.00 | 0.00 | 0.01 | 0.05 | 0.00 | 0.00 | 0.00 | -0.03 | 0.26 |
| D50%F | 0.00 | -0.05 | 0.00 | -0.01 | 0.03 | 0.15 | 0.00 | 0.01 | 0.01 | 0.02 | 0.04 |
| DM | 0.02 | 0.03 | -0.01 | 0.00 | 0.01 | -0.03 | 0.00 | 0.07 | 0.00 | 0.05 | 0.06 |
| HLPB | -0.04 | 0.08 | 0.00 | 0.01 | -0.01 | 0.16 | 0.00 | 0.00 | 0.01 | -0.02 | 0.17 |
| PH | 0.04 | -0.06 | 0.00 | 0.00 | -0.02 | 0.67 | 0.00 | 0.06 | 0.01 | 0.00 | $0.56^{*}$ |
| PTL | 0.03 | -0.08 | 0.00 | -0.01 | 0.01 | 0.41 | 0.00 | 0.03 | 0.00 | -0.01 | 0.26 |
| IFL | 0.07 | -0.13 | 0.00 | -0.01 | 0.00 | 0.65 | 0.00 | 0.01 | 0.01 | -0.01 | $0.52^{*}$ |
| NBPP | 0.06 | -0.13 | 0.00 | 0.00 | 0.00 | 0.25 | 0.00 | 0.04 | 0.00 | 0.00 | -0.08 |
| STY | 0.00 | -0.12 | 0.00 | 0.00 | -0.01 | 0.37 | 0.00 | 0.02 | 0.00 | -0.02 | $0.35^{*}$ |
| LL | 0.01 | -0.06 | 0.00 | 0.00 | -0.02 | 0.09 | 0.00 | -0.03 | -0.01 | -0.02 | 0.10 |
| VN | **0.16** | -0.14 | 0.00 | -0.01 | 0.01 | 0.42 | 0.00 | -0.01 | 0.03 | 0.00 | $0.40^{**}$ |
| NPPP | 0.07 | **0.31** | 0.03 | 0.00 | 0.00 | -0.55 | 0.00 | 0.02 | 0.02 | 0.01 | $0.26^{**}$ |
| PL | 0.02 | -0.09 | **0.03** | 0.01 | -0.03 | 0.12 | 0.00 | -0.02 | 0.00 | -0.03 | $-0.02^{**}$ |
| PT | -0.05 | 0.05 | 0.01 | **0.03** | -0.02 | -0.17 | 0.00 | -0.01 | 0.00 | -0.01 | -0.14 |
| NSPP | 0.02 | 0.03 | -0.01 | -0.01 | **0.29** | -0.11 | 0.00 | -0.03 | -0.20 | -0.02 | $-0.12^{**}$ |
| SWPP | 0.07 | -0.18 | 0.00 | -0.01 | -0.01 | **0.96** | 0.00 | 0.01 | 0.01 | 0.01 | $0.80^{**}$ |
| Pr | 0.02 | 0.06 | -0.01 | 0.00 | 0.01 | 0.02 | **0.00** | 0.03 | -0.02 | -0.01 | 0.08 |
| P | 0.01 | -0.03 | 0.01 | 0.00 | 0.02 | -0.09 | 0.00 | **-0.16** | 0.00 | -0.03 | -0.11 |
| Ca | 0.06 | -0.04 | 0.00 | 0.00 | 0.02 | 0.17 | 0.00 | 0.01 | **0.07** | 0.00 | 0.21 |
| Fe | 0.00 | 0.02 | -0.01 | 0.00 | -0.01 | 0.10 | 0.00 | 0.03 | 0.00 | **0.14** | 0.21 |

DFE= Day to 50% emergence, DFF= Days to first flowering, D50%F= Day to 50% flowering, DM= Day to maturity, HLPB=Height lowest primary branch, PH=Plant height (cm), PTL=Petiole length, IFL=Inflorescence length, NBPP=Number of branch/plant, ST=Stem thickness, LL=Leaf length, VN=Verticil number, NPPP=Number of Pod/plant, PL=Pod length, PT=Pod thickness, NSPP= Number of seeds per pod, SWPP=Seed weight/plant, GY=Grain yield, Pr=Protein, P=Phosphorus, Ca=Calcium, Fe=Iron

## 4 Conclusion

Inflorescence length and verticil number at genotypic and phenotypic levels, days to first flowering and number of branches per plant at the genotypic level and plant height and stem thickness at phenotypic level showed positive and significant correlation with grain yield. Seed weight per plant, protein and iron and phosphorus contents of grain, days to first flowering, leaf length and plant height exerted high to moderate positive direct effects on grain yield at the genotypic level. These traits had high to moderate positive indirect effects via each other and through Seed weight per plant, the protein content of grain and calcium on grain yield at the genotypic level suggested simultaneous selection for grain yield and these traits are possible. Seed weight per plant, number of pods per plant, inflorescence length, petiole length, verticil number, protein content of grain, plant height, calcium via number of seed per plant, verticil number and phosphorus content of grain could be used for indirect selection of genotypes for grain yield since these traits were less influenced by environmental factors and had high to moderate positive direct and/or indirect effects on grain yield at genotypic level. Therefore, these traits should be used for selection during white lupin crop improvement in breeding and further study will required on its contribution to improved agricultural sustainability, food security and reduce malnutrition which has close associations with known day challenge climate change..

## Conflicts of Interest

Conflicts of Interest authors declare that they have no conflicts of interest.

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