French bean (Phaseolus vulgaris L.; 2n = 2x = 22), an internationally important food legume, is under cultivation since ancient times and consumed as either green pod or dry seeds after cooking. It is also known as kidney bean, common bean, field bean, garden bean, faras bean, rajmash, bush bean, pole bean, navy bean, haricot bean, check bean, string bean and snap bean. French bean belongs to the family Leguminaceae under sub-family papilionaceae. Southern Mexico and Central America are considered to be the primary centre of origin, while secondary centre of origin lies in Peruvian - Ecuadorian - Bolivian area. Correlation is useful for making rational improvement in yield and its components but these does not provide an exact picture of the relative importance of direct and indirect influences of each of these component characters. Moreover, when more and more variables are included, the indirect contribution becomes complex. In such situation it becomes necessary to study path coefficient analysis which takes into account the causal relationship in addition to degree of relationship. The relationship between productivity and its components in French bean have frequently been examined. The present study was undertaken to understand and confirm the extent and nature of inter-relationship as well as the direct and indirect effects of pod yield components in seventy germplasm of French bean. For path analysis, pod yield per plant had the highest direct effect on pod yield per hectare followed by plant height, seed yield per plant, 100 seed weight and pod length. The highest negative direct effect was observed by days to 50 per cent flowering, number of pods per plant, number of pods per cluster and number of primary branches.

**MATERIAL AND METHODS**

In present investigation, fifty five germplasm were evaluated for their genetic variability, character associations and their direct and indirect effects on pod yield per hectare during January - May, 2009 at Vegetable Research Centre (VRC), G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar (Uttarakhand). Geographically, Pantnagar is situated at the latitude of 29°N, longitude 79.3°E and at an altitude of 243.84 meters above the mean sea level. The university falls under the subtropical zone and situated in the Tarai region at the foothills of Shivalik range of the Himalayas.

The experiment was laid out in randomized block design with three replications. The spacing was 50 cm x 10 cm. The field was prepared by one deep ploughing followed by three harrowing and clod breaking, hoeing and leveling. The field was divided into plots. The N: P: K fertilizers were applied @120:60:40 kg ha⁻¹. Half dose of nitrogen with full dose of phosphorus and potassium were applied as basal dose at the time of field preparation and remaining nitrogen was applied as top dressing in two split doses. Nitrogen was applied in the form of urea and phosphorus in form of ammonium phosphate and potash as murate of potash. The cultural operations like weeding, hoeing, irrigation, spraying of chemicals against disease and insects etc. were done as per need. Five randomly selected plants were tagged in each row and used for recording the observations. The observations were recorded for plant height (cm), number of primary branches per plant, days to 50% flowering, number of pods per pod cluster, number of pods per plant, pod length (cm), pod yield per hectare (q/hectare) and seed yield per plant (g). The mean values of each genotypes...
in each replication for all the traits were subjected to statistical analysis as per Randomized Block Design. The component of direct and indirect effects of 10 characters on pod yield per hectare were estimated using path coefficient analysis\(^6\).

**RESULTS AND DISCUSSION**

Correlation is useful for making rational improvement in yield and its components but these does not provide an exact picture of the relative importance of direct and indirect influences of each of these component characters. Moreover, when more and more variables are included, the indirect contribution becomes complex\(^5\)\(^6\). In such situation it becomes necessary to study path coefficient analysis which takes into account the causal relationship in addition to degree of relationship.

In present investigation, path-coefficient analysis, revealed that pod yield (0.825) per plant had the highest direct effect on pod yield per hectare followed by plant height (0.265), seed yield per plant (0.122), 100 seed weight (0.101) and pod length (0.089). The highest negative direct effect was observed by days to 50 per cent flowering (-0.030), number of pods per plant (-0.099), number of pods per cluster (-0.226), number of primary branches (-0.392) and days to 50 per cent maturity (-0.456) at phenotypic level (Table-1 and 2). These findings are in congruity with those of earlier workers\(^7\)\(^-\)\(^12\). Similar to present study also revealed that the number of primary branches was the major component trait influencing green pod yield from 16 cultivars of common bean\(^14\). This finding is similar to some workers\(^13\) who had also reported negative direct effect of days to flowering and pod length on pod yield. For the character plant height substantial role of the direct effect was observed. However, lower the correlation came into feature due to the negative indirect effect imposed through number of pods per cluster (0.054). Plant height imposed indirect positive effect on pod yield per hectare through number of pods per cluster (0.054), seed yield per plant (0.033), 100 seed weight (0.031) and pod yield per plant (0.018). While negative indirect effect on pod yield per hectare via days to 50 per cent flowering (-0.013), number of pods per plant (-0.035), number of primary branches per plant (-0.057), pod length (-0.060) and days to 50 per cent maturity (-0.215). It may be concluded that a considerable role of the positive or negative counterbalance occurred in most of the characters ultimately result in their corresponding correlation coefficient. Number of primary branches imposed positive indirect effect through days to 50 per cent maturity (0.323), plant height (0.388), pod yield per plant (0.031), number of pod per cluster (0.022), pod length (0.017), number of pods per plant (0.014) and seed yield per plant (0.005) showed highly significant positive indirect effect on pod yield per hectare. While characters like days to 50 per cent flowering (-0.004) and 100 seed weight (-0.018) showed negative indirect effect on pod yield per hectare. Days to 50 per cent flowering contributed positive effect on pod yield per plant (0.187), plant height (0.117), 100 seed weight (0.035), seed yield per plant (0.007), number of pods per cluster (0.005) and negative indirect effect on pod yield per hectare was observed by number of pods per plant (-0.001), pod length (-0.018), days to 50 per cent maturity (-0.018) and number of primary branches (-0.058).

Positive indirect effect on pod yield per hectare via Days to 50 per cent maturity was observed for the characters like number of primary branches per plant (0.278), pod yield per plant (0.197), plant height (0.125), number of pods per cluster (0.102), 100 seed weight (0.042) and seed yield per plant (0.026). Number of pods per cluster contributed positive indirect effect on yield per hectare via days to 50 per cent maturity (0.206), number of primary branches (0.038), pod length (0.037), number of pods per plant (0.004), days to 50 per cent flowering (0.001) and 100 seed weight (0.001). While negative indirect effect was contributed seed yield per plant (-0.015), plant height (-0.064) and pod yield per plant (-0.076). The character like number of pods per plant imposed indirect effect through plant height (0.094), seed yield per plant (0.079), number of primary branches (0.057) and number of pods per cluster (0.010). While days to 50 per cent flowering (-0.000) has more indirect effect on pod yield per hectare followed by 100 seed weight (-0.006), pod length (-0.027), pod yield per plant (-0.047) and days to 50 per cent maturity (-0.116). Pod length imposed indirect positive effect on pod yield per hectare through days to 50% maturity (0.251), number of pods per plant (0.300), days to 50 per cent flowering (0.006) and characters like 100 seed weight (-0.022), seed yield per plant (-0.030), number of primary branches (-0.074), number of pods per cluster (-0.095), pod yield per plant (-0.120) and plant height (-0.180) imposed negative indirect effect for pod yield per hectare.

Pod yield per plant contributed towards yield per hectare via number of pods per cluster (0.020), 100 seed weight (0.007),
Table 1. Mean performance of different genotypes for important quantitative characters in French bean

<table>
<thead>
<tr>
<th>S. N</th>
<th>CHARACTERS</th>
<th>MAX</th>
<th>MIN</th>
<th>MEAN</th>
<th>PROMISING LINES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Plant height (cm)</td>
<td>15.16</td>
<td>74.41</td>
<td>52.86</td>
<td>FB-12, FB-25, FB-14, FB-18</td>
</tr>
<tr>
<td>2.</td>
<td>No. of primary branches per plant</td>
<td>3</td>
<td>4</td>
<td>33.69</td>
<td>FB-3, FB-45</td>
</tr>
<tr>
<td>3.</td>
<td>Days to 50% flowering</td>
<td>59</td>
<td>64.93</td>
<td>64.44</td>
<td>VLFB-130, VLFB-412, VLFB-1</td>
</tr>
<tr>
<td>4.</td>
<td>Days to 50% maturity</td>
<td>78.67</td>
<td>81.60</td>
<td>80.35</td>
<td>FB-12, VLFB -1, Pant Bean -3, Pant Anupama</td>
</tr>
<tr>
<td>5.</td>
<td>No. of pods per cluster</td>
<td>1.4</td>
<td>2.67</td>
<td>16.72</td>
<td>Pant Bean-2 (2.67), Pant Anupma, FB-36, FB-14</td>
</tr>
<tr>
<td>7.</td>
<td>Pod length (cm)</td>
<td>8.13</td>
<td>11.80</td>
<td>95.22</td>
<td>Pant Anupma, FB-45, Pant Bean-2</td>
</tr>
<tr>
<td>8.</td>
<td>Pod yield per plant (g)</td>
<td>47.29</td>
<td>12.91</td>
<td>91.45</td>
<td>FB-7, FB-13, FB-10, VLFB-413</td>
</tr>
<tr>
<td>9.</td>
<td>Pod yield /hectare (g)</td>
<td>31.21</td>
<td>107.52</td>
<td>60.35</td>
<td>FB-7, FB-13, FB-10, VLFB-413</td>
</tr>
<tr>
<td>10.</td>
<td>Seed yield /plant (g)</td>
<td>33.3</td>
<td>56.68</td>
<td>52.61</td>
<td>FB-19, FB-20, Pant Bean-3, FB-13, FB-16, FB-17, FB-27</td>
</tr>
<tr>
<td>11.</td>
<td>100 seed weight (g)</td>
<td>25.53</td>
<td>46.65</td>
<td>30.07</td>
<td>FB-8, FB-36, FB-14, FB-7, FB-35, FB-6, FB-16, FB-5</td>
</tr>
</tbody>
</table>

Residual factor = 0.5056

plant height (0.006), number of pods per plant (0.005) and seed yield per plant (0.002). While negative indirect effect contributed yield per hectare via days to 50 per cent flowering (-0.007), pod length (-0.013), number of primary branches (-0.015) and days to 50 per cent maturity (-0.109). The character like seed yield per plant imposed positive effect through plant height (0.073), number of pods per cluster (0.029) and pods yield per plant (0.016) beside these characters like days to 50 per cent flowering (-0.001), 100 seed weight (-0.016), number of primary branches (-0.017), pod length (-0.022), number of pods per plant (-0.064) and days to 50 per cent maturity (-0.098) imposed indirect effect on pod yield per hectare. Positive indirect effect on pod yield per hectare via 100 seed weight was observed for the characters like plant height (0.084), number of primary branches per plant (0.072), pod yield per plant (0.016) and number of pods per plant (0.006). While
negative indirect effect on pod yield per hectare via number of pods per cluster (-0.004), days to 50 per cent flowering (-0.011), seed yield per plant (-0.019), days to 50 per cent maturity (-0.194) and plant length (-0.200).

At genotypic level it was found that pod yield per plant has highest direct effect (0.606) on pod yield per hectare. Positive direct effect on the pod yield hectare was also observed with days to 50 per cent flowering (0.119), days to 50 per cent maturity (0.053), seed yield per plant (0.016), number of primary branches per plant (0.003). The highest negative direct effect was observed with 100 seed weight (-0.004), number of pods per cluster (-0.009), number of pods per plant (-0.023), pod length (-0.089) and plant height (-0.108). The character plant height imposed highest positive indirect effect on pod yield per hectare through pod length (0.056), days to 50 per cent flowering (0.052), pod yield per plant (0.013), days to 50 per cent maturity (0.011), seed yield per plant (0.004), number of pods per cluster (0.001) and number of primary branches per plant (0.001). While 100 seed weight (-0.001) and number of pods per plant (-0.007) has negative indirect effect on pod yield per hectare. Positive indirect effect on the pod yield per hectare via number of primary branches per plant was recorded the character via pod yield per plant (0.008), pod length (0.003), days to 50 per cent flowering (0.001), number of pods per plant (0.001), seed yield per plant (0.001) and 100 seed weight (0.000). While negative indirect effect observed for the characters like days to 50 per cent maturity (-0.000) and number of pods per cluster (-0.001), and plant height (-0.003). Days to 50 per cent flowering contributed positive effect on pod yield per plant (0.136), pod length (0.017), number of pods per cluster (0.001), seed yield per plant (0.001), number of primary branches per plant (0.000) and negative indirect effect on pod yield per hectare was observed by days to 50 per cent maturity (-0.000), number of pods per plant (-0.001), 100 seed weight (-0.001) and plant height (-0.047).

Positive indirect effect on pod yield per hectare via Days to 50 per cent maturity was observed for the characters like pod yield plant (0.068), pod length (0.016), number of pods per cluster (0.001) and seed yield per plant (0.001). While negative indirect effect on number of primary branches per plant (-0.000), days to 50 per cent flowering (-0.000), 100 seed weight (-0.001), number of pods per plant (-0.002) and plant height (-0.024). Number of pods per cluster contributed positively
REFERENCES