The economic value of a crop plant lies in its produce. As for the UV-B impacts, most of the plants have suffered from growth reductions which would lead to yield reductions. Most of the growth chamber studies where the interplay of other environmental factors are selectively excluded, recorded only adverse effects. The present study is to evaluate the yield attributes of ten varieties viz. CW-122, COVU-1, COFC-8, CO-1, COVU-2, KM-1, CO-6, VAMBAN, CO-3 and PUDUVAl of cowpea, Vigna unguiculata (L.) Walp. after exposure to supplementary UV-B radiation (2 hours daily @ 12.2 kJ m$^{-2}$ d$^{-1}$; ambient = 10 kJ m$^{-2}$ d$^{-1}$). Mature fruits were harvested periodically from each plant and the length and weight of the pod, number of seeds per pod and number of seeds per plant and weight of seeds per plant were recorded. Supplemental UV-B exposure consistently decreased the entire yield components per plant basis, decreasing the pod number by 40 to 66.66 %, pod weight by 23.87 to 68.02 %, pod length by 6.14 to 48.21 %, seed number by 30.76 to 86.20 % and seed mass by 49.17 to 89.98 %. However, number of seeds produced per pod by COFC-8, COVU-2 and PUDUVAl levelled with control. Harvest index was the least in CW-122 (-68.25 %) after UV-B treatment. KM-1 and CO-3 topped the list (-13.52 to -14.19 %) followed by CO-1 (-42.28 %) under UV-B. UV-B stressed COFC-8, COVU-1, CO-6, VAMBAN, PUDUVAl and COVU-2 occupied next positions (-42.94 to -62.80 %).

**Keywords:** Ultraviolet-B, Cowpea, Ten Varieties, Yield Attributes

**INTRODUCTION**

Cowpea (Vigna unguiculata (L.) Walp.) is one of the most important food legume crops in the semi arid tropics covering Asia, Africa, southern Europe and Central and South America. A drought-tolerant and warm-weather crop, cowpeas are well-adapted to the drier regions of the tropics, where other food legumes do not perform well. It also has the useful ability to fix atmospheric nitrogen through its root nodules, and it grows well in poor soils with more than 85% sand and with less than 0.2% organic matter and low levels of phosphorus (Singh et al., 2003).

In addition, it is shade tolerant, so is compatible as an intercrop with maize, millet, sorghum, sugarcane and cotton. This makes cowpeas an important component of traditional intercropping systems, especially in the complex and elegant subsistence farming systems of the dry savannas in sub-Saharan Africa (Singh, et al., 2003). In these systems the haulm (dried stalks) of cowpea is a valuable by-product, used as animal feed. Researchers have found that selecting early generations of cowpea crops to increase yield is not an effective strategy, while other methods such as bulk breeding are more efficient in developing high-yield varieties (Singh, et al., 2003).

New varieties of cowpea with high yield are introduced in India more frequently, but their adaptation to elevated UV-B remains doubtful. Although increases in UV-B flux severely affects foliage (Kokilavani and Rajendiran, 2013; Kokilavani and Rajendiran, 2014), suppresses plant growth (Rajendiran and Ramanujam, 2003; Rajendiran and Ramanujam, 2004) and inhibits nodulation and nitrogen metabolism (Rajendiran and Ramanujam, 2006; Rajendiran and Ramanujam, 2003; Sudaroli and Rajendiran, 2013a; Sudaroli and Rajendiran, 2013b; Arulmozhi and Rajendiran, 2014; Vijayalakshmi and Rajendiran, 2014) in sensitive crops, the objective of the present study was to find out the best out of the ten varieties of cowpea that can tolerate supplementary UV-B irradiation.

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MATERIALS AND METHODS
Cowpea (*Vigna unguiculata* (L) Walp.), the nitrogen fixing grain legume was chosen for the study. Viable seeds of the ten varieties of cowpea viz. CW-122, COVU-1, COFC-8, CO-1, COVU-2, KM-1, CO-6, VAMBAN, CO-3 were procured from Saravana Farms, Villupuram, Tamil Nadu and PUDUVAI from local farmers in Pondicherry. The seeds were selected for uniform colour, size and weight and used in the experiments. The crops were grown in pot culture in the naturally lit greenhouse (day temperature maximum 38 ± 2 ºC, night temperature minimum 18 ± 2 ºC, relative humidity 60 ± 5 %, maximum irradiance (PAR) 1400 μmol m⁻² s⁻¹, photoperiod 12 to 14 h). Supplementary UV-B radiation was provided in UV garden by three UV-B lamps (*Philips TL20W/12 Sunlamps*, The Netherlands), which were suspended horizontally and wrapped with cellulose diacetate filters (0.076 mm) to filter UV-C radiation (< 280 nm). UV-B exposure was given for 2 h daily from 10:00 to 11:00 and 15:00 to 16:00 starting from the 5th day after sowing. Plants received a biologically effective UV-B dose (UV-B_{BE}) of 12.2 kJ m⁻² d⁻¹ equivalent to a simulated 20 % ozone depletion at Pondicherry (12º2’N, India). The control plants, grown under natural solar radiation, received UV-B_{BE} 10 kJ m⁻² d⁻¹. Mature fruits were harvested periodically from each plant and the length and weight of the pod, number of seeds per pod and number of seeds per plant and weight of seeds per plant were recorded. Harvest index (Mohan *et al.*, 1992) and shelling percentage (Francis *et al.*, 1978) were calculated using the following formulae.

\[
\text{Harvest index} = \frac{\text{Yield of the plant (g)}}{\text{Biomass of the plant (g)}} \times 100
\]

\[
\text{Shelling percentage} = \frac{\text{Seed wt. plant}^{-1}}{\text{Fruit wt. plant}^{-1}} \times 100
\]

At least ten replicates were maintained for all treatments and control. The experiments were repeated to confirm the trends. The result of single linkage clustering (Maskay, 1998) was displayed graphically in the form of a diagram called dendrogram (Everstt, 1985). The term dendrogram is used in numerical taxonomy for any graphical drawing giving a tree-like description of a taxonomic system. The similarity indices between the ten varieties of cowpea under study were calculated using the formula given by Bhat and Kudesia (2011).

\[
\text{Similarity index} = \frac{\text{Total number of similar characters}}{\text{Total number of characters studied}} \times 100
\]

Based on the similarity indices between the ten varieties of cowpea, dendrograms were draw to derive the interrelationship between them and presented in tables and plates.

RESULTS AND DISCUSSION
Supplemental UV-B exposure consistently decreased the entire yield components per plant basis, the decreases being 40 to 66.66 % in the pod number, 23.87 to 68.02 % in pod weight, 6.14 to 48.21% in pod length, 30.76 to 86.20 % in seed number and 49.17 to 89.98 % in seed mass (Table 1, Plates 1, 2). Analysed on the basis of number of seeds per pod, only the UV-B treated plants had more fruits with fewer number of seeds. The three varieties viz., COFC-8, COVU-2 and PUDUVAI yielded fruits with same number of seeds compared to control (Table 1, Plates 1, 2).

Harvest index was the least in CW-122 variety of cowpea after UV-B treatment which showed severe reduction of 68.24 % compared with control. Despite UV-B stress CO-3 and KM-1 recorded only little reduction of harvest index by 14.18 and 13.51% respectively when compared with the performances of the respective control crops. A similar pattern was obtained for data on shelling percentage also (Table 1, Plates 1, 2).
Plate 1: Harvested pods of ten varieties of *Vigna unguiculata* (L) Walp. on 60 DAS. (1: Control, 2: UV-B)
Figure 1: CW-122

Figure 2: COVU-1

Figure 3: COFC-8

Figure 4: CO-1

Figure 5: COVU-2

Figure 6: KM-1

Figure 7: CO-6

Figure 8: VAMBAN

Figure 9: CO-3

Figure 10: PUDUVAI

Plate 2: Harvested seeds of ten varieties of *Vigna unguiculata* (L) Walp. on 60 DAS. (1: Control, 2: UV-B)

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Plate 3: Dendrogram showing the interrelationship between the ten varieties of Vigna unguiculata (L.) Walp. in yield attributes under supplementary UV-B
Table 1: Changes in yield components of ten varieties of *Vigna unguiculata* (L.) Walp. under control and supplementary UV-B exposed conditions

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Treatment</th>
<th>Pod number plant$^{-1}$</th>
<th>Single pod wt. (g)</th>
<th>Pod wt. plant$^{-1}$ (g)</th>
<th>Length of the pod (cm)</th>
<th>Seed number pod$^{-1}$</th>
<th>Seed number plant$^{-1}$</th>
<th>Seed mass pod$^{-1}$ (g)</th>
<th>Seed mass plant$^{-1}$ (g)</th>
<th>Shelling percentage</th>
<th>Harvest index</th>
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<tbody>
<tr>
<td>CW-122</td>
<td>Control</td>
<td>10</td>
<td>2.160</td>
<td>13.22</td>
<td>13.86</td>
<td>12</td>
<td>120</td>
<td>2.001</td>
<td>12.92</td>
<td>97.66</td>
<td>64.11</td>
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<td></td>
<td>UV-B</td>
<td>5</td>
<td>1.514</td>
<td>2.185</td>
<td>11.35</td>
<td>10</td>
<td>39</td>
<td>0.804</td>
<td>1.758</td>
<td>80.47</td>
<td>20.36</td>
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<tr>
<td>COVU-1</td>
<td>Control</td>
<td>4</td>
<td>1.375</td>
<td>2.964</td>
<td>10.64</td>
<td>5</td>
<td>13</td>
<td>0.874</td>
<td>2.257</td>
<td>76.13</td>
<td>25.74</td>
</tr>
<tr>
<td></td>
<td>UV-B</td>
<td>2</td>
<td>0.742</td>
<td>1.145</td>
<td>9.25</td>
<td>4</td>
<td>9</td>
<td>0.889</td>
<td>1.027</td>
<td>89.69</td>
<td>14.20</td>
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<td>COFC-8</td>
<td>Control</td>
<td>3</td>
<td>0.913</td>
<td>1.815</td>
<td>9.66</td>
<td>8</td>
<td>15</td>
<td>0.561</td>
<td>1.393</td>
<td>76.75</td>
<td>13.16</td>
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<td></td>
<td>UV-B</td>
<td>1</td>
<td>0.612</td>
<td>0.612</td>
<td>8.56</td>
<td>8</td>
<td>8</td>
<td>0.422</td>
<td>0.422</td>
<td>68.95</td>
<td>7.51</td>
</tr>
<tr>
<td>CO-1</td>
<td>Control</td>
<td>4</td>
<td>1.512</td>
<td>3.418</td>
<td>11.47</td>
<td>8</td>
<td>22</td>
<td>1.230</td>
<td>3.052</td>
<td>89.27</td>
<td>18.26</td>
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<tr>
<td></td>
<td>UV-B</td>
<td>2</td>
<td>0.691</td>
<td>1.039</td>
<td>9.63</td>
<td>4</td>
<td>7</td>
<td>0.500</td>
<td>0.823</td>
<td>80.07</td>
<td>10.45</td>
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<td>COVU-2</td>
<td>Control</td>
<td>3</td>
<td>1.023</td>
<td>2.773</td>
<td>9.72</td>
<td>4</td>
<td>11</td>
<td>0.610</td>
<td>2.071</td>
<td>74.68</td>
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<tr>
<td></td>
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<td>0.525</td>
<td>0.525</td>
<td>8.13</td>
<td>4</td>
<td>4</td>
<td>0.520</td>
<td>0.520</td>
<td>98.99</td>
<td>8.99</td>
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<tr>
<td>KM-1</td>
<td>Control</td>
<td>5</td>
<td>1.759</td>
<td>3.807</td>
<td>13.23</td>
<td>12</td>
<td>43</td>
<td>1.296</td>
<td>3.377</td>
<td>88.71</td>
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<td></td>
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<td>1.050</td>
<td>1.974</td>
<td>11.64</td>
<td>8</td>
<td>15</td>
<td>0.985</td>
<td>1.716</td>
<td>86.93</td>
<td>16.83</td>
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<td>CO-6</td>
<td>Control</td>
<td>4</td>
<td>1.139</td>
<td>3.296</td>
<td>11.45</td>
<td>9</td>
<td>32</td>
<td>1.053</td>
<td>3.034</td>
<td>92.02</td>
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<td>0.867</td>
<td>10.73</td>
<td>7</td>
<td>7</td>
<td>0.671</td>
<td>0.671</td>
<td>77.45</td>
<td>8.54</td>
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<tr>
<td>VAMBAN</td>
<td>Control</td>
<td>4</td>
<td>1.485</td>
<td>2.931</td>
<td>11.22</td>
<td>12</td>
<td>29</td>
<td>1.265</td>
<td>2.499</td>
<td>85.24</td>
<td>17.29</td>
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<tr>
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<td>UV-B</td>
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<td>0.789</td>
<td>0.789</td>
<td>5.81</td>
<td>4</td>
<td>4</td>
<td>0.655</td>
<td>0.655</td>
<td>82.94</td>
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<td>CO-3</td>
<td>Control</td>
<td>5</td>
<td>1.230</td>
<td>3.607</td>
<td>12.82</td>
<td>11</td>
<td>40</td>
<td>1.046</td>
<td>3.071</td>
<td>85.14</td>
<td>20.86</td>
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<td></td>
<td>UV-B</td>
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<td>0.457</td>
<td>1.384</td>
<td>10.83</td>
<td>7</td>
<td>13</td>
<td>0.375</td>
<td>1.144</td>
<td>82.67</td>
<td>17.90</td>
</tr>
<tr>
<td>PUDUVAI</td>
<td>Control</td>
<td>3</td>
<td>0.559</td>
<td>1.248</td>
<td>3.14</td>
<td>4</td>
<td>12</td>
<td>0.466</td>
<td>0.981</td>
<td>78.60</td>
<td>26.88</td>
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<td></td>
<td>UV-B</td>
<td>1</td>
<td>0.179</td>
<td>0.179</td>
<td>2.44</td>
<td>4</td>
<td>4</td>
<td>0.098</td>
<td>0.098</td>
<td>54.91</td>
<td>10.23</td>
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</table>

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UV-B exposure delayed the flowering and reduced the yield in crop plants in general (Caldwell and Flint, 1994; Rajendiran and Ramanujam, 2004). Both the timing of flowering and the number of flowers produced in maize cultivars, *Petunia hybrida*, *Brassica rapa* and several mono- and dicotyledonous ephemerals have been altered by UV-B (Staxen and Bornman, 1994; Musil, 1995; Klaper et al., 1996; Mark et al., 1996; Rajendiran and Ramanujam, 2004). Since the success of pollination is linked to the availability of pollinators, any phonological dislocation would affect the reproductive success greatly (Caldwell, 1968; Ziska et al., 1992; Staxen and Bornman, 1994; Musil, 1995; Klaper et al., 1996; Mark et al., 1996; Rajendiran and Ramanujam, 2004).

In fact, the reproductive organs like pollen and ovules have effective protective features. The UV-B absorbing compounds are abundant in the floral parts (sepals and petals) and more specifically on the walls of pollens and ovaries (Day and Demchik, 1996). Though very little work has been done on the phenological changes, even minor alterations could adversely affect the agricultural systems. Simulating a 40 % ozone reduction, Esser (1980) found the yield of potato reduced by 41 %, spinach by 66 %, cabbage by 49 % and bean by 75 % and for a 20 % ozone depletion the yield of green gram was decreased by 25 to 45 % (Rajendiran and Ramanujam, 2004). In 1991, Giller observed the yield of cotton and soybean reduced by 23 and 25% respectively under field conditions also. Supplementary UV-B altered the DNA and protein, which in turn altered the vital metabolisms including photosynthesis reflecting them in the form of reduced yield and nutrition content in the grains (Rajendiran and Ramanujam, 2003; Rajendiran and Ramanujam, 2004).

The yield attributes assessed in ten varieties of cowpea showed differences in pod number, pod length, pod weight, seed number, seed mass, shelling percentage per plant and harvest index after irradiation with supplementary UV-B on 60 DAS. The similarity index value between CO-6, COFC-8 and VAMBAN was 75 %. These three varieties remained as one group and showed close relationship with CW-122. The similarity index between CO-3 and KM-1 was the highest with 100% value, which together formed a group with CO-6, COFC-8, VAMBAN and CW-122. On the other hand, CO-I, COVU-1, COVU-2 and

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PUDUVAI together had 100 % similarites and were kept far away from rest of the varieties (Table 2; Plate 3). To conclude, out of the ten varieties of cowpea taken for screening against UV-B impact, CO-3 and KM-1 have proved to be the best UV-B tolerant varieties.

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