GERMINATION ECOLOGY AND MANAGEMENT OF *Portulaca oleracea* L.

Thesis

Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
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MASTER OF SCIENCE
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BOTANY
(Minor Subject: Biochemistry)

By

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CERTIFICATE I

This is to certify that the thesis entitled, **"Germination ecology and management of *Portulaca oleracea* L."** submitted for the degree of M.Sc., in the subject of **Botany** (Minor subject: **Biochemistry**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Harnoor Kaur (L-2017-BS-253-M)** under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE II

This is to certify that the thesis entitled, **"Germination ecology and management of *Portulaca oleracea* L."** submitted by **Harnoor Kaur (L-2017-BS-253-M)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **M.Sc.**, in the subject of **Botany** (Minor subject: **Biochemistry**) has been approved by the Student's Advisory Committee after an oral examination on the same.

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ABSTRACT

The present study entitled, "Germination ecology and management of *Portulaca oleracea* L." was conducted to evaluate the effect of seed priming, various environmental factors viz., temperature, light, salinity, pH, moisture stress and seed burial depth on germination and early seedling growth of this weed. The effect of different pre-emergence herbicides on emergence of *P. oleracea* was also studied. Seed priming with gibberellic acid was effective in breaking seed dormancy. Soaking of seeds in 1000 ppm GA for 24 hrs was found to be most effective in overcoming seed dormancy. Optimum temperature required for germination of *P. oleracea* was 30°C and either increase or decrease in temperature from 30°C, decreased germination. Germination of this weed was found to be independent of light, thus it can emerge under tree and crop canopies in both non-cropped and cropped areas. Germination decreased with increase in NaCl concentration from 0 to 250 mM and was completely inhibited at 300 mM NaCl. *P. oleracea* was able to germinate over a pH range of 6.5 to 8.5. There was decrease in germination with decrease in osmotic potential from 0 to -0.8 MPa and germination was completely inhibited at -1.0 MPa. Germination was inhibited by 50% at 163.56 mM NaCl and -0.51 MPa osmotic potential. Seedling emergence was greater when seeds were present on soil surface. Seedling emergence decreased with increase in seed burial depth and no emergence was observed when seeds were buried at soil depth greater than 2 cm. Decrease in seedling emergence may be co-related with small seed size and limited storage reserves which are insufficient to support seedling emergence from deeper soil layers. Emergence of *P. oleracea* seeds was found to be inhibited by all the tested herbicides viz., oxyfluorfen (240, 180 and 120 g/ha), pendimethalin (750, 563 and 375 g/ha), sulfentrazone (360, 270 and 180 g/ha), oxadiargyl (90, 68 and 45 g/ha) and clomazone (400, 300 and 200 g/ha).

Key words: Light, moisture stress, *Portulaca*, salinity, temperature

Signature of Major Advisor **Signature of the Student**

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ਮੌਜੂਦਾ ਅਧਿਐਨ "*ਪੋਰਟੁਲਾਕਾ ਓਲੀਰੇਸੀਆ* ਐਲ. ਦੀਆਂ ਪੁੰਗਰਨ ਪ੍ਰਸਥਿਤੀਆਂ ਅਤੇ ਪ੍ਰਬੰਧਨ" ਸਿਰਲੇਖ ਅਧੀਨ ਇਸ ਨਦੀਨ ਦੇ ਪੁੰਗਰਨ ਅਤੇ ਜਲਦੀ ਵਾਧੇ ਉਪਰ ਬੀਜ ਪਰਾਇਮਿੰਗ ਦੇ ਪ੍ਰਭਾਵ, ਵੱਖੋ-ਵੱਖਰੇ ਵਾਤਾਵਰਣਕ ਕਾਰਕਾਂ ਜਿਵੇਂ ਕਿ ਤਾਪਮਾਨ, ਰੋਸ਼ਨੀ, ਖਾਰੇਪਣ, ਪੀ.ਐਚ., ਪਾਣੀ ਦੀ ਕਮੀ ਅਤੇ ਬੀਜਾਈ ਸਮੇਂ ਬੀਜ ਦੀ ਡੂੰਘਾਈ ਦੇ ਪ੍ਰਭਾਵ ਦਾ ਮੁਲਾਂਕਣ ਕਰਨ ਦੇ ਲਈ ਕੀਤਾ ਗਿਆ। *ਪੀ. ਓਲੀਰੇਸੀਆ* ਦੀ ਉਤਪਤੀ ਉਪਰ ਵੱਖੋ-ਵੱਖਰੇ ਨਦੀਨ ਨਾਸ਼ਕਾਂ ਦੇ ਪ੍ਰਭਾਵ ਦਾ ਅਧਿਐਨ ਵੀ ਕੀਤਾ ਗਿਆ। ਜਿਬਰੈਲਿਕ ਐਸਿਡ ਨਾਲ ਬੀਜ ਦੀ ਸੁਧਾਈ ਕਰਨਾ ਬੀਜ ਨਿਰਪੱਖਤਾ ਨੂੰ ਤੋੜਨ ਵਿੱਚ ਵਧੇਰੇ ਅਸਰਦਾਰ ਸੀ। ਬੀਜਾਂ ਨੂੰ 1000 ਪੀ.ਪੀ.ਐਮ. ਜ਼ਿਬਰੈਲਿਕ ਐਸਿਡ ਵਿੱਚ 24 ਘੰਟਿਆਂ ਤੱਕ ਭਿਓਂ ਕੇ ਰੱਖਣਾ, ਬੀਜਾਂ ਦੀ ਨਿਰਪੱਖਤਾ ਨੂੰ ਖਤਮ ਕਰਨ ਵਿੱਚ ਵਧੇਰੇ ਅਸਰਦਾਰ ਸਾਬਿਤ ਹੋਇਆ। *ਪੀ. ਓਲੀਰੇਸੀਆ* ਦੀ ਉਤਪਤੀ ਲਈ 30°C ਤਾਪਮਾਨ ਸਭ ਤੋਂ ਵਧੇਰੇ ਅਨੁਕੂਲ ਸੀ ਅਤੇ ਤਾਪਮਾਨ ਦੇ 30°C ਤੋਂ ਘੱਟਣ ਜਾਂ ਵੱਧਣ ਨਾਲ ਇਸਦੀ ਉਤਪਤੀ ਵਿੱਚ ਕਮੀ ਦਰਜ ਕੀਤੀ ਗਈ। ਇਸ ਨਦੀਨ ਦੀ ਉਤਪਤੀ ਉਪਰ ਰੋਸ਼ਨੀ ਦੀ ਕੋਈ ਭੂਮਿਕਾ ਨਹੀਂ ਸੀ ਇਸ ਕਰਕੇ ਇਹ ਨਦੀਨ ਖੇਤਾਂ ਵਿੱਚ ਜਾਂ ਖਾਲੀ ਖੇਤਰਾਂ ਵਿੱਚ ਦਰਖਤਾਂ ਜਾਂ ਫ਼ਸਲਾਂ ਹੇਠਾਂ ਉੱਗ ਸਕਦਾ ਹੈ। ਸੋਡੀਅਮ ਕਲੋਰਾਈਡ ਦੀ ਘਣਤਾ ਵਿੱਚ 0 ਤੋਂ 250 mM ਤੱਕ ਵਾਧਾ ਹੋਣ ਨਾਲ ਇਸ ਨਦੀਨ ਦੀ ਉਤਪਤੀ ਵਿੱਚ ਕਮੀ ਦਰਜ ਕੀਤੀ ਗਈ ਅਤੇ ਸੋਡੀਅਮ ਕਲੋਰਾਈਡ ਦੀ 300 mM ਘਣਤਾ ਉਪਰ ਇਸ ਨਦੀਨ ਦਾ ਵਾਧਾ ਪੂਰਨ ਤੌਰ ਤੇ ਰੁੱਕ ਗਿਆ। ਅਧਿਐਨ ਦੌਰਾਨ ਦੇਖਿਆ ਗਿਆ ਕਿ *ਪੀ. ਓਲੀਰੇਸੀਆ* ਨਦੀਨ 6.5 ਤੋਂ 8.5 ਪੀ.ਐਚ. ਉਪਰ ਪੁੰਗਰਨ ਦੇ ਸਮਰੱਥ ਸੀ। ਓਸਮੈਟਿਕ ਪੋਟੈਂਸ਼ੀਅਲ ਵਿੱਚ 0 ਤੋਂ -0.8 MPa ਤੱਕ ਕਮੀ ਆਉਣ ਨਾਲ ਨਦੀਨ ਦੇ ਪੁੰਗਰਨ ਵਿੱਚ ਕਮੀ ਆਈ ਅਤੇ -1.0 MPa ਉਪਰ ਇਸਦੀ ਪੁੰਗਰਨਤਾ ਪੂਰਨ ਤੌਰ ਤੇ ਬੰਦ ਹੋ ਗਈ। 163.56 mM ਸੋਡੀਅਮ ਕਲੋਰਾਈਡ ਅਤੇ -0.51 MPa ਓਸਮੈਟਿਕ ਪੋਟੈਂਸ਼ੀਅਲ ਉਪਰ ਨਦੀਨ ਦੀ ਪੁੰਗਰਨਤਾ ਵਿੱਚ 50% ਤੱਕ ਕਮੀ ਦਰਜ ਕੀਤੀ ਗਈ। ਜਦੋਂ ਬੀਜ ਮਿੱਟੀ ਦੀ ਸੱਤ੍ਹਾ ਉੱਪਰ ਮੌਜੂਦ ਸਨ ਤਾਂ ਬੀਜਾਂ ਦੇ ਪੁੰਗਰਨ ਦੀ ਦਰ ਸਭ ਤੋਂ ਵਧੇਰੇ ਸੀ। ਬੀਜਾਂ ਦੀ ਡੂੰਘਾਈ ਵਿੱਚ ਵਾਧਾ ਹੋਣ ਨਾਲ ਬੀਜਾਂ ਦੀ ਪੁੰਗਰਨਤਾ ਵਿੱਚ ਕਮੀ ਆਈ ਅਤੇ ਜਦੋਂ ਬੀਜਾਂ ਨੂੰ 2 ਸੈ.ਮੀ. ਤੋਂ ਵਧੇਰੇ ਗਹਿਰਾਈ ਤੇ ਬੀਜਿਆ ਗਿਆ ਤਾਂ ਬੀਜਾਂ ਦੀ ਪੁੰਗਰਨਤਾ ਵਿੱਚ ਪੂਰਨ ਤੌਰ ਤੇ ਕਮੀ ਆਈ। ਬੀਜਾਂ ਦੇ ਪੁੰਗਰਨ ਵਿੱਚ ਆਈ ਕਮੀ ਦਾ ਕਾਰਨ ਛੋਟੇ ਅਕਾਰ ਦੇ ਬੀਜ ਅਤੇ ਸੀਮਿਤ ਖਾਦ ਭੰਡਾਰ ਹੋ ਸਕਦਾ ਹੈ। ਅਧਿਐਨ ਵਿੱਚ ਜਾਂਚੇ ਸਾਰੇ ਨਦੀਨ ਨਾਸ਼ਕਾਂ ਜਿਵੇਂ ਕਿ ਓਕਸੀਫਲੋਰੋਫੇਨ (240, 180 ਅਤੇ 120 ਗ੍ਰਾ/ਹੈਕਟੇਅਰ), ਪੈਂਡੀਮੈਥਾਲਿਨ (750, 563 ਅਤੇ 375 ਗ੍ਰਾ/ਹੈਕਟੇਅਰ), ਸਲਫੈਨਟ੍ਰਾਜ਼ੋਨ (360, 270 ਅਤੇ 180 ਗ੍ਰਾ/ਹੈਕਟੇਅਰ), ਓਕਸਾਡਾਈਐਰੀਜ਼ਾਇਲ (90, 68 ਅਤੇ 45 ਗ੍ਰਾਮ/ਹੈਕਟੇਅ) ਅਤੇ ਕਲੋਮਾਜ਼ੋਨ (400, 300 ਅਤੇ 200 ਗ੍ਰਾਮ/ਹੈਕਟੇਅਰ) ਦੀ ਵਰਤੋਂ ਨਾਲ *ਪੀ. ਓਲੀਰੇਸੀਆ* ਦੇ ਪੁੰਗਰਨ ਵਿੱਚ ਕਮੀ ਆਈ।

ਮੁੱਖ ਸ਼ਬਦ: *ਪੋਰਟੁਲਾਕਾ,* ਖਾਰਾਪਣ, ਤਾਪਮਾਨ, ਪਾਣੀ ਦੀ ਘਾਟ, ਰੋਸ਼ਨੀ

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CHAPTER-I

INTRODUCTION

Portulaca oleracea L. (Parsley and Purslane), is an annual dicot weed belonging to family Portulacaceae. *P. oleracea*, a C_4 species is inhabitant of South America (Proctor 2013), North Africa (Chapman *et al* 1974), Western Asia (Mitich 1997). *P. oleracea* is a problematic weed of about 45 crops (Chauhan and Johnson 2009). It is troublesome weed in different parts of the world infesting various crops viz., wheat (*Triticum aestivum*), sugarcane *(Saccharum officinarum*), tea (*Camellia sinensis*), cotton (*Gossypium hirtsutum*) and various vegetable crops (Amini and Abdi 2014). In Punjab, it is emerging as a major weed in many summer vegetable crops like bell pepper (*Capsicum annuum*), summer squash (*Cucurbita pepo*) and sponge gourd (*Luffa cylindrica*).

Besides being a weed, *P. oleracea* is cultivated as a vegetable crop. The leaves of the young plants are used as salad and seeds are also edible. *P. oleracea* is one of the important medicinal plants with anti-hypoxic effect (Chen *et al* 2009), used in Chinese traditional medicines (Niu and Dan 2005), cure asthma (Malek *et al* 2004), reduce inflammation (Wang *et al* 2007) and has also anti-pain and antimicrobial effects (Behravan *et al* 2011), antioxidant properties (Lim and Quah 2007, Chan *et al* 2000); and ethanol extract of *P. oleracea* has neuroprotective effects against hypoxia injury (Wanyin *et al* 2012). The leaves of *P. oleracea* are rich in α-linolenic acid and antioxidants like α-tocopherol, β-carotene, and glutathione (Simopoulos *et al* 1992). Leaves of *P. oleracea* have high amount of melatonin which is beneficial for human health and also prevent cancer growth (Simopoulos *et al* 2005, Allegra *et al* 2003, Cuzzocrea *et al* 1999). Melatonin has antioxidative properties and performs role in diurnal regulation as a plant hormone-like molecule (Kolar and Machackova 2005). It is a rich source of potassium (494 mg/100 g), magnesium (68 mg/100 g), calcium (65 mg/100 g), crude proteins (17.9%), crude fibers (20.3%) and fats (5.6%). *P. oleracea* and *P. tuberosa* are hyperaccumulators and are adapted to grow naturally on contaminated soils by accumulating and detoxifying high load of metals and metalloids. Tiwari *et al* (2008) observed that both species of *Portulaca* accumulated high levels of chromium in roots when treated with industrial effluent whereas high level of iron accumulation was observed when plants were irrigated with tube well water.

P. oleracea is a succulent annual weed with glabrous, reddish stems that branch radially from the central axis forming a mat up to 60 cm in diameter with alternate, opposite leaves which are succulent, sessile and broad-rounded at the tips. Root consists of thick taproot as well as fibrous lateral roots. Flowers are yellow

and can self-pollinate (Zimmerman 1976). Under low light intensity, *P. oleracea* flowers are cleistogamous and fully expand only on bright hot days (Miyanishi and Cavers 1980). Fruit is a capsule that contains many brownish-black and shiny seeds of 0.5 to 0.8 mm diameter. Seeds are hydrophilous and anemophilous and viable up to 40 years. *P. oleracea* is a vigorous weed that grows rapidly by vegetative propagation. In a single cycle of reproduction, *P. oleracea* has ability to produce about 10,000 seeds (Chauhan and Johnson 2009). In tropics and warmer regions, *P. oleracea* completes its life cycle within 2-3.5 months while it takes 4 months to complete its life cycle in cooler regions (Proctor 2013). Egley (1974) reported that seed dormancy in *P. oleracea* was mainly related to seed age and water content. Less mature seeds germinated more readily than mature seeds with lower water content.

Germination of weeds is affected by various environmental factors like light, temperature, salinity, pH, osmotic potential, seed burial depth (Karlsson *et al* 2008). Light is important prerequisite for seed germination of only some species. Germination of seeds is inhibited with increasing depth of sowing, due to limited availability of light and storage reserves; and development of secondary dormancy at greater depths. Temperature plays a key role in seed germination, with some weeds germinating only at particular temperature while others germinate in a broad range of temperature. Salinity, pH and osmotic stress are also important factors that influence seed germination and emergence of seedlings. *P. oleracea* has potential to withstand extreme environmental conditions viz., high temperature, light intensity, salinity and pH. During drought conditions, this weed operates photosynthetic processes through CAM metabolism (Koch and Kennedy 1980) and during sufficient water availability, it operates C_4 metabolism (Abdullatif *et al* 2016).

Crop losses due to weeds can be reduced either by manual weeding or by use of herbicides. Some pre-emergence herbicides used for suppressing *P. oleracea* are clomazone, sulfentrazone, bensulide, diethatyl, diphenamid. In US, sulfentrazone (0.28 kg/ha) was able to control 74% of *P. oleracea* in pumpkin (Brown and Masiunas 2002). Bensulide (5.6 kg/ha) was effective in controlling *P. oleracea* by 52-98% in lettuce, in Salinas (Italy) (Haar and Fennimore 2003). *P. oleracea* was suppressed by 84% in leafy green vegetables like leafy turnip *(Brassica rapa*), mustard (*Brassica rapa),* cabbage (*Brassica oleracea*), broccoli *(Brassica oleracea)* and kale (*Brassica oleracea*) by diethatyl and diphenamid (Cavero *et al* 1996). In Spain, clomazone (0.36 kg/ha) was 72% effectual in controlling *P. oleracea* in pepper (*Capsicum annuum*). Postemergence herbicides effective for controlling *P. oleracea* are imazethapyr, phenamedipham, oxyfluorfen (Proctor and Reicher 2013).

However, most of these herbicides have been found to exert severe crop damage. Ghosheh (2004) reported that post-emergence application of oxyfluorfen (1200 g/ha) at 3-4 leaf stage of onion was successful in controlling *P. oleracea*, but caused enormous crop injury to onion. Dusky and Stall (1996) observed that crop vigor of lettuce was reduced, leading to loss of crop yield by post-emergence application of imazethapyr (0.67 kg/ha).

Germination of seeds and emergence of seedlings in response to various environmental factors is a key in understanding of weed seed dynamics in soil for improving weed management strategies. In Punjab, *P. oleracea* is a major weed of vegetable crops which are dicotyledonous and very sensitive to most of the post-emergence herbicides available in the market like nitrofen, imazethapyr, oxyfluorfen and phendimethalin. This emphasizes the need to study the germination ecology of this weed and to evaluate the effect of pre-emergence herbicides for formulating the management strategies against *P. oleracea* infestation in vegetable crops.

The objectives of the present study were:

i. To study the effect of environmental factors on germination ecology of *Portulaca oleracea.*
ii. To study the efficacy of pre-emergence herbicides for management of *P. oleracea*

CHAPTER-II

REVIEW OF LITERATURE

Weeds are the major cause of low crop yields as they have ability to compete with crops for their common resources. Weed species affect crop growth and yield by allelopathy (Amini *et al* 2009) or competition (Amini *et al* 2014). *Portulaca oleracea* (Parsley and Purslane), is an annual dicot weed belonging to family Portulacaceae. The genus *Portulaca* consists of 100 species that are distributed throughout tropics and sub-tropics but very rare in temperate regions (Nyffeler and Eggli 2010). The family Portulacaceae consist of 21 genera and about 580 species (Uddin *et al* 2014). *P. oleracea*, a C_4 species is inhabitant of South America (Proctor 2013), North Africa (Chapman *et al* 1974) and Western Asia (Mitich 1997). It is a troublesome weed of wheat (*Triticum aestivum*), sugarcane (*Saccharum officinarum*), tea (*Camellia sinensis*), cotton (*Gossypium hirtsutum*) and various vegetable crops (Amini and Abdi 2014). In Punjab, it is emerging as a major weed in many summer vegetable crops like bell pepper (*Capsicum annuum*), summer squash (*Cucurbita pepo*) and sponge gourd (*Luffa cylindrica)*.Other weeds that infest summer vegetable crops are madhana (*Eleusine indica*), takri (*Digitaria sanguinalis*), makra (*Dactyloctenium aegyptium*), nut grass (*Cyperus rotundus*) etc.

P. oleracea has glabrous, reddish stems that form a mat up to 60 cm in diameter and root may consist of either thick taproot or fibrous lateral roots. Leaves are succulent, sessile, alternate or opposite and broad-rounded at the tips. Inflorescence is terminal, much congested and head-like, surrounded by 2–several involucral leaves, rarely an open cyme (Walters and Figueiredo 2011). The flowers are yellow and can self-pollinate (Zimmerman 1976). Fruit is a capsule that consist of many brownish-black and shiny seeds of 0.5 to 0.8 mm diameter. Seeds are usually hydrophilous and anemophilous and viable up to 40 years. *P. oleracea* is a vigorous weed that grows rapidly by vegetative propagation. In a single cycle of reproduction, *P. oleracea* has ability to produce about 10,000 seeds (Chauhan and Johnson 2009).

Accurate information regarding abiotic factors that are essential for seed germination is important for effective weed control. Seed germination is influenced by various abiotic factors such as pH, light intensity, temperature, salt concentration in soil, osmotic stress (Ganepour *et al* 2004). Seeds of *P. oleracea* germinate in presence of light, indicating that they are positively photoblastic. Germination (63%) was greatest for seeds present on the soil surface or near the soil surface as seeds were able to receive sunlight (Chauhan and Johnson 2009). Benvenuti *et al* (2001) reported that seed size may also affect germination when buried deep in the

soil as small seeds may not have enough energy reserves essential for germination. Moist environment favour seed germination while drought inhibits seed germination (Chauhan and Johnson 2009). The information regarding different factors that influence seed germination is described below:

(A) Seed Dormancy: Causes and methods of breaking

Seed germination incorporates those events that start with uptake of water by dry seed and terminate with the elongation of the embryonic axis (Bewley and Black 1994). Germination is said to be complete when radicle penetrate out of the embryo. Seed germination usually depends on temperature, light, pH, salinity and water availability. Requirement of temperature, light, pH, salinity and water are species-specific (Egley and Duke 1985). Seed dormancy may be attributed to immaturity of embryo, impermeability of seed coat to water or gas, inhibition of embryo development because of mechanical reasons, particular requirements of temperature or light and presence of inhibitory substances of the germination. There are three types of dormancy, namely innate, enforced and induced dormancy. Seeds that do not germinate even under normal environmental conditions are innately dormant seeds while enforced dormant seeds are those which don't germinate under unfavourable environment. Induced dormancy has also been referred to as secondary dormancy. In this case, the dormancy is induced upon the seed after conditions of innate and enforced dormancy have been broken or lost from the seed.

There are many methods of breaking seed coat imposed dormancy viz., soaking in hot water, sulphuric acid treatment, scarification, potassium nitrate and gibberellic acid treatment (Bhardwaj *et al* 2016). Yazdanshenas *et al* (2015) reported that seed dormancy in *P. oleracea* is due to its hard seed coat. Balouchi and Sanavy (2006) reported different methods to overcome seed dormancy in *Medicago radiata, M. polymorpha* and *M. rigidula*. They found that 750 ppm gibberellic acid with prechilling at 4°C was most effective in breaking seed dormancy of *Medicago radiata*; whereas 96% sulphuric acid proved to be very helpful in breaking seed dormancy in *M. polymorpha* and *M. rigidula*. Prechilling provide winter conditions to seed which is beneficial for inducing seed germination in species like *Portulaca oleracea* and *Echinacea angustifolia* (Macchia *et al* 2001). Yazdanshenas *et al* (2015) dipped seeds of *P. oleracea* in water for12 hrs followed by drying for 12 hrs for a week which increased germination percentage to about 45%. Pre-chilling and potassium nitrate were 40% effectual in increasing germination as compared to 25% germination in control. Treating the *P. oleracea* seeds with potassium nitrate (0.1 g L^{-1}), for 24 hrs provided nutrients to seed and was responsible for causing significant increase in root and shoot growth along with increased seed germination.

(B) Environmental factors affecting seed germination

2.1 Light and temperature

Temperature and light are the major factors affecting seed germination. Requirement of temperature and light is species specific. Some species better germinate under constant temperature while others under alternate day and night temperature. Positively photoblastic seeds can germinate only in presence of light while negatively photoblastic seeds can germinate only in dark. However, some non-photoblastic seeds can germinate equally in light and dark. Chauhan and Johnson (2009) observed that germination of *P. oleracea* (population of Philippines) was affected by interaction between temperature and light. In complete darkness, germination was about 1 to 2% and was not influenced by temperature. But in the light/dark regime germination was 70, 75 and 81% at 25/15, 35/25 and 30/20°C, respectively. Burke *et al* (2003) observed 30, 43 and 35% seed germination of *Dactyloctenium aegyptium* at 25, 30 and 35°C, respectively. Chauhan and Johnson (2008a) observed that seeds of *Eleusine indica* (population from Philippines) were able to germinate at 35/15, 30/20 and 25/15°C, with highest germination (68%) at 30/20°C and lowest germination (5%) at 25/15°C. At 12-h photoperiod, *Caperonia palustris* germination decreased from 50 to 0% with decrease in temperature from 30 to 10°C. When exposed to alternate day/night temperatures, *Caperonia palustris* seed germination was maximum at 40/30°C (54%) and declined to 28% at 30/20°C and no germination was recorded at 20/10°C (Koger *et al* 2004). Optimum temperature for broadleaf weed species hairy beggarticks (*Bidens pilosa*) and redvine (*Brunnichia ovata*) weeds is 25 to 35 and 35°C, respectively (Reddy and Singh 1992, Shaw *et al* 1991). Asgarpour *et al* (2015) observed that *Chamaesyce maculata* seeds did not germinate at temperature of 20/10°C but 19.5% seeds germinated at 25/15°C temperature and maximum germination (> 90%) was found to occur in temperature range of 35/25, 40/30 and 45/35°C. The germination rate of *Chamaesyce maculata* increased from 1 seed per day to 10 seeds per day directly with the increase in the temperature regime from 25/15 to 40/30°C and then dropped to 5 seeds per day at 45/35°C. Chauhan *et al* (2006a) reported that the rate of germination is closely correlated with soil temperature. Tanveer *et al* (2013) observed that germination percentage of *Trianthema portulacastrum* increased from 65 to 85% with rise in temperature from 25 to 35°C whereas germination declined to 71.25 % at 45°C. Chauhan and Johnson (2008b) reported that the seeds of *Eclipta prostrata* were able to germinate at 25/15, 30/20 and 35/25°C with germination percentage of about 76, 93 and 87 % respectively, indicating ability of this weed to emerge throughout the year at low altitudes in tropical countries. Chauhan and

Johnson (2008c) reported that optimum temperature for germination of *Digitaria ciliaris* and *Digitaria longiflora* was 35/25°C. At alternating temperature of 25/15°C about 39 and 75% seeds of *Digitaria ciliaris* and *Digitaria longiflora* germinated respectively. No seed of *Digitaria longiflora* germinated in dark, but few (3 to 7%) seeds of *Digitaria ciliaris* germinated in dark. Optimum temperature for germination of *Rottboellia cochinchinensis* is 25/15°C in both light and dark (Bolfrey-Arku *et al* 2011).

2.2 pH

Emergence of seedlings is also influenced by pH of soil. Some species require optimum pH to germinate and grow while others can tolerate extremes of pH levels (Evetts and Burnside 1972). About 70% seeds of *Portulaca oleracea* were able to germinate between pH range of 5-9 (Chauhan and Johnson 2009). At pH 4, germination was completely inhibited. In US, Burke *et al* (2003) observed that there was decrease in germination of *Dactyloctenium aegyptium* with rise in pH. Maximum germination (65%) was observed at pH 4 and only 5% seeds germinated at pH 9. *Eleusine indica* population of Philippines was able to germinate in pH range of 5-10 (Chauhan and Johnson 2008a). Chauhan *et al* (2006b) exposed the seeds of *Malva parviflora* to pH range of 4 to 10 and observed 50% germination between pH 4 and 6.3. Germination reduced from 50 to 30% when pH was increased from 6.3 to 10. Koger *et al* (2004) reported increase in germination of summer annual weed, *Caperonia palustris* from 30 to 50% with increase in pH from 4 to 8 and further increase in pH to 10, reduced germination to 30%. Asgarpour *et al* (2015) observed that germination of *Chamaesyce maculata* was unaffected by the tested levels of pH. Germination was 95% over a broad pH range from 4 to 10. This indicates that pH would not be a limiting factor for germination of this weed. Maximum germination (>80%) of *Trianthema portulacastrum* occurred at pH range of 8-10 (Tanveer *et al* 2013). Rezvani and Fani Yazdi (2013) observed that seeds of *Solanum nigrum* were able to germinate in wide range of pH (4-10) with highest germination (95%) at pH 7. Chauhan and Johnson (2008b) reported that more than 85% seeds of *Eclipta prostrata* germinated in pH range of 4 to 10. Chauhan and Johnson (2008c) observed that *Digitaria ciliaris* and *Digitaria longiflora* germinated over pH range of 5 to 10 indicating that both species are well adapted to wide range of soil conditions.

2.3 Salinity

Seed germination is also influenced by salt concentration. High salinity inhibits seed germination by preventing water from entering the seed. The common cations associated with salinity are Na^{+}, Cl^{+} and Mg^{2+} while the common anions are

Cl^-, SO_4^{2-} and HCO_3^-. However, Na^+ and Cl^- ions are mainly responsible for toxicity in plants (Yadhav *et al* 2011). Both germination rates and root growth of seedlings are affected by salinity. Salinity has affected about 6% of the total land area of the world. Areas of world adversely affected by salinity are parts of USA, Australia, Israel and Mediterranean Basin (Aringhieri 2010). In India, some parts of states viz., Bihar, Delhi, Haryana, Punjab, Rajasthan and Uttar Pradesh are affected by salinity. The districts of Punjab that are adversely affected by salinity are Sri Muktsar Sahib, Faridkot, Bathinda and Sangrur (Shakya and Singh 2010). Salinity is also a major problem by which 6.8 mha (33%) area of cultivated land of Pakistan is affected (Anonymous 2008). Out of 20.36 million hectare of cultivable land, 6.3 million is affected by salinity in Pakistan (Qureshi and Barret-Lennard 1998). Chauhan and Johnson (2009) observed that germination of *P. oleracea* can occur under NaCl concentration from 0 to 200 mM. Increasing salinity from 0 to 106 mM reduced the germination from 90 to 50% with complete inhibition at 250 mM. Chauhan and Johnson (2008a) reported that germination of *E. indica* was maximum in control (>90%) with only 25% germination at 100 mM NaCl. Chauhan *et al* (2006b) reported that seeds of *Malva parviflora* germinated at all NaCl concentrations upto 160 mM NaCl with greatest (58%) germination at 0 mM NaCl and lowest (2%) at 160 mM NaCl. Koger *et al* (2004) observed that *Caperonia palustris* seed germination was greater than 52% between 10 to 40 mM NaCl and was lowest (27%) at 160 mM NaCl. Asgarpour *et al* (2015) observed that maximum germination (85%) of *Chamaesyce maculate* occurred at 20 mM NaCl and it dropped to 36.5% at 120 mM NaCl and was completely inhibited at 160 mM NaCl. Salinity also adversely affects germination of *Trianthema portulacastrum*. Tanveer *et al* (2013) observed that 80% seeds of *T. portulacastrum* germinated in 0-150 mM NaCl concentration and then germination decreased to 10% with increase in salt concentration to 250 mM. Rezvani and Fani Yazdi (2013) observed significant effect of salinity on seed germination of *Solanum nigrum.* They reported gradual decrease in germination from 90 to 22% with increase in NaCl concentration from 0 to 160 mM. Chauhan and Johnson (2008b) reported 83, 50, 37 and 0% germination of *Eclipta prostrata* at 150, 194, 200 and 250 mM NaCl. Chauhan and Johnson (2008c) observed that increase in salt concentration have greater influence on germination of *Digitaria longiflora* than *Digitaria ciliaris*. 80% seeds of both species were able to germinate at 0 mM salt concentration while few seeds of *Digitaria ciliaris* germinated at 200 mM and no seed of *Digitaria longiflora* was able to germinate at 200 mM.

4.4 Osmotic stress

When plant is exposed to osmotic stress, it exhibits a wide range of molecular and cellular responses (Greenway and Munns 1980). Osmotic potential of the germination media also affects seed germination. Osmotic stress delays the onset of seed germination, reduces the rate of seed germination and decreases germination percentage (Patane *et al* 2013). Polyethylene glycol is the most preferred chemical for simulating moisture stress conditions under controlled conditions in the laboratory because it is metabolically inactive and its large molecular mass prevents entry of this chemical into the seed (Berkat and Briske 1982, Hohl and Peter 1991). At -1.0 MPa osmotic potential, seed germination of *Portulaca oleracea* was completely suppressed. Germination was reduced to 50% at -0.34 MPa as compared to 80-90% germination observed at 0 MPa (Chauhan and Johnson 2009). Chauhan (2011) reported that with decrease in osmotic potential from 0 to -0.6 MPa, seed germination of *D. aegyptium* was reduced from 90 to 9%. At -0.8 MPa, germination of this weed was completely inhibited. Germination of *E. indica* was reduced from 92 to 5% with reduction in osmotic potential from 0 to -0.6 MPa (Chauhan and Johnson 2008a). Chauhan *et al* (2006b) observed steep decrease in germination (50 to 20%) of *Malva parviflora* (little mallow) seeds when osmotic potential was decreased from 0 to -1.0 MPa. Germination was completely inhibited at -0.6 MPa, which indicates that seeds are moderately sensitive to low water potential. The seedling emergence of round-leaved mallow (*Malva rotundifolia*) decreased below the soil water potential of -0.28 MPa (Blackshaw 1990). Such conditions can occur temporarily in between the rainfall events at the start of the growing season in southern Australia. Makowski and Morrison (1989) reported that major infestations of round leaved mallow generally occur in regions of western Canada where relative precipitation levels are high. Koger *et al* (2004) reported linear decrease in germination of *Capronia palustris* ($y= -9.2x+6.8$, $R^2= 0.94$) as osmotic potential was increased from 0 to 0.8 MPa. *Chamaesyce maculata* germination decreased from 98 to 23.5% as water potential decreased from 0 to -0.6 MPa and no germination was observed at -0.8 MPa. Germination exceeded 80% at water potentials of 0 to -0.4 MPa. These results suggest that the spread of *Chamaesyce maculata* is possibly restricted to moist soils because of its inability to germinate under low soil moisture conditions. Tanveer *et al* (2013) reported that decrease in osmotic potential from 0 to -0.8 MPa decreased germination of *T. portulacastrum* from 100 to 20% and 85.5 to 25% in one year and five year old seeds, respectively. Rezvani and Fani Yazdi (2013) noticed crucial effect of osmotic potential on germination of *Solanum nigrum*. With decrease in osmotic potential

from 0 to -0.5 MPa, there was sudden decrease in seed germination percentage from 95 to 0%. Chauhan and Johnson (2008b) recorded that germination of *Eclipta prostrata* declined from 94 to 2% as osmotic potential was decreased from 0 to -0.8 MPa and germination was completely inhibited at -1 MPa. Chauhan and Johnson (2008c) reported about 80% seed germination in *Digitaria ciliaris* and *Digitaria longiflora* at 0 MPa. Germination of *Digitaria longiflora* was completely inhibited at -1.0 MPa while few seeds of *Digitaria ciliaris* were able to germinate at -1.0 MPa. Bolfrey-Arku *et al* (2011) reported that maximum germination (93%) of *Rottboellia cochinchinensis* occurred at 0 MPa while minimum germination (9%) occurred at -0.8 MPa.

2.5 Seed burial depth

Seed germination depends on depth at which seed is buried. Seeds present close to soil surface receive considerable amount of light to germinate as compared to seeds buried at great depth. Reduction in seedling emergence with increased seed burial depth may be due to seed size, as seeds buried too deep may not have sufficient energy reserves required for seedling emergence (Chauhan and Johnson 2009). When seeds of *P. oleracea* were present on soil surface, 63-81% of seeds germinated. Seed germination was completely inhibited at depth of 2 cm (Chauhan and Johnson 2009). Burke *et al* (2003) found that 40% of American population of *D. aegyptium* germinated at depth of 1 cm. Only 1% seeds were able to germinate at depth of 6 cm. *E. indica* seeds (Philippines population) exhibited 82% germination when seeds were present on soil surface. At 0.5 and 6 cm depth, seed germination was reduced to 63 and 4% respectively. Seed germination of this weed was completely inhibited at burial depth of 8 cm (Chauhan and Johnson 2008a). Koger *et al* (2004) reported emergence of *Capronia palustris* seedlings was greater than 67% for seeds placed on the soil surface and decreased with increased planting depth. 15% of seeds germinated when buried at 7.5 cm. No seedling emergence was observed when seeds were placed at a depth of 10 cm. Tanveer *et al* (2013) recorded about 80% emergence when seeds of *T. portulacastrum* were placed at soil surface. As the seeds were buried deep in the soil, germination percentage was decreased with 0% seed germination at 5 cm depth. Seed burial depth has considerable effect on seedling emergence of *Solanum nigrum* (Rezvani and Fani Yazdi 2013). There was 40% germination when seeds were scattered on soil surface but no seedling emergence was observed at a depth of 4 cm. Chauhan and Johnson (2008c) reported that seed germination of *Digitaria ciliaris* and *Digitaria longiflora* was highly affected by increasing seed burial depth. Maximum germination (>90%) of both species was observed when seeds were sown on soil surface. Germination of

Digitaria longiflora was inhibited at depth deeper than 1 cm, while 5% seedling emergence of *Digitaria ciliaris* was observed at depth of 6 cm. Bolfrey-Arku *et al* (2011) reported that maximum (78%) number of seeds of *Rottboellia cochinchinensis* germinated when sown on the soil surface. Germination percentage declined to 12% with increase in seed burial depth to 4 cm. Low or lack of seed germination when buried deep in the soil could be due to hypoxia, low rate of gaseous diffusion (Benvenuti 2003).

(C) Herbicides for management of *P. oleracea*

1) Pre-emergence herbicides

Imazethapyr (0.067 kg/ha) was effective in controlling 91% of *P. oleracea* in lettuce (Norsworthy and Smith 2005). Diethatyl (4.5 kg/ha), diphenamid (4 kg/ha), and diethatyl combined with diphenamid were successful in controlling *P. oleracea* in *Capsicum annuum* (Cavero *et al* 1996). Some other pre-emergence herbicides used for suppressing *P. oleracea* are clomazone (0.36 kg/ha), sulfentrazone (0.28 kg/ha), bensulide (5.6 kg/ha), diethatyl, diphenamid (Sherwani *et al* 2015). Clomazone belonging to isoxazolidinone is an inhibitor of the pigment-synthesis. Sulfentrazone is a phenyl triazolinone herbicide (Theodoridis *et al* 1992) and it inhibits protoporphyrinogen oxidase (protox) in plants, a key intermediate in both heme and chlorophyll biosynthesis (Jacobs and Jacobs 1987). Deli and Warren (1970) reported that diphenamid (N,N-dimethyl-2,2-diphenylacetamide) is a reversible metabolic inhibitor, it's application inhibited cell division in the root tip by limiting utilization of substrates in the cells, therefore caused reduction of root and shoot growth. In US, sulfentrazone (0.28 kg/ha) was able to control 74% of *P. oleracea* in pumpkin (Brown and Masiunas 2002). Bensulide (5.6 kg/ha) was effective in controlling *P. oleracea* by 52-98% in lettuce in Salinas (Italy) (Haar and Fennimore 2003). *P. oleracea* was suppressed by 84% in leafy green vegetables like leafy turnip *(Brassica rapa*), mustard (*Brassica rapa)*, cabbage (*Brassica oleracea*), broccoli *(Brassica oleracea)* and kale (*Brassica oleracea*) by diethatyl and diphenamid (Cavero *et al* 1996). In Spain, clomazone (0.36 kg/ha) was 72% effectual in controlling *P. oleracea* in pepper (*Capsicum annuum*). At US, sulfentrazone (0.28kg/ha) caused more than 45% crop damage to pumpkin (Brown and Masiunas 2002). In Spain, Cavero *et al* (2001) observed crop yield loss of bell pepper due to clomazone (0.36 kg/ha). Hoyt *et al* (1996) observed that when napropamide (2 kg ai/ha) was applied to cabbage crop infested by *P. oleracea*, it was able to control *P. oleracea* by 93%. Fennimore *et al* (2001) recorded that different concentrations of S-metolachor viz., 0.56, 0.72, 1.06 and 1.41 kg/ha were 95% effective in controlling *P. oleracea*, while 3.4 kg/ha cycloate killed 96% of *P. oleracea*. Proctor and

Reicher (2013) conducted experiment in 2012, which reported that isoxaben (1 kg/ha), simazine (1.4 kg/ha) were 95% effective in controlling *P. oleracea* while siduron (27.4 kg/ha), dithiopyr (0.3 kg/ha), dimethenamid (0.8 kg/ha) were 50% successful in controlling *P. oleracea.*

2) Post-emergence herbicides

Post-emergence herbicides are effective in killing and/or suppressing emerged seedlings of weeds. Gorske and Hopen (1978) noticed that application of post emergence herbicides like nitrofen and oxyfluorfen increased membrane permeability, which caused stomatal closure, membrane disruption, synthesis of ethylene and finally leaf abscission in *P. oleracea*. Post-emergence herbicides effective in controlling *P. oleracea* are imazethapyr (0.067 kg/ha), phenamedipham (0.86 kg/ha) and oxyfluorfen (1200 g/ha) (Proctor and Reicher 2013). More than 85% of *P. oleracea* in lettuce was controlled by application of imazethapyr (Dusky and Stall 1996). About 45% of *P. oleracea* in leafy greens was controlled by phenamedipham (0.37 kg/ha) (Norsworthy and Smith 2005). Oxyfluorfen (1200 g ai/ha) was effectual in controlling 95% *Portulaca oleracea* in onion (Ghosheh 2004). However, many of these herbicides caused severe crop damage. Phenmedipham (0.37 kg/ha) caused 54-82% injury to mustard greens (Norsworthy and Smith, 2005). Ghosheh (2004) reported that post-emergence application of oxyfluorfen (1200 g/ha) at 3-4 leaf stage of onion was successful in controlling *P. oleracea*, but caused enormous crop injury to onion. Gorske and Hopen (1978) treated *P. oleracea* plants with 0.56 kg/ha nitrofen and 0.28 kg/ha oxyfluorfen and herbicide effect was observed after 2 hrs for 24 hrs. After 4 hrs of treatment, stomata began to close and remained closed until leaf abscission occured 8-24 hrs after treatment. Stomatal closure caused increase in the leaf temperature which further elevated ethylene production and initiated leaf abscission. Proctor and Reicher (2013) reported that best *P. oleracea* control (100%) was provided by metsulfuron-methyl (0.04 kg/ha), fluroxypyr (0.31 kg/ha) and triclopyr (1.55 kg/ha).

CHAPTER - III

MATERIALS AND METHODS

3.1 LOCATION AND CLIMATE

The present investigation entitled, "Germination ecology and management of *Portulaca oleracea* L." was conducted at Research Farm and Seed Physiology Laboratory, Office of Director (Seeds), Punjab Agricultural University, Ludhiana.

3.2.1 PLANT MATERIAL

Seeds of *P. oleracea* were collected from vegetable fields of district Sri Muktsar Sahib during the months of June-July 2016 to 2018. Collected seeds were cleaned and stored in airtight plastic containers till further use in experimentation. The weight of 1000 seeds of *P. oleracea* was 1.40 g (Plate 1).

Plate 1: Seeds of *Portulaca oleracea* L.

3.2.2 GERMINATION PROTOCOL

Seeds of *Portulaca oleracea* were sterilized using mercuric chloride (0.1%) for two minutes and then washed twice with distilled water to protect them from any fungal infection. Seed germination was evaluated by placing 20 seeds in a Petri dish lined with double layers of Whatman No.1 filter paper, which was moistened with 4 ml of treatment solution. Germination was studied in 3 replicates and Petri dishes were incubated at 30°C (optimum temperature) in an environmental chamber (MAC MSW-127). Seeds germinated using distilled water only served as control. Number of seeds germinated were counted at 24 hour intervals till 15 days after start of the experiment. The visible protrusion of the radicle was taken as the germination criteria. 15 days old seedlings were analysed for various physiological parameters.

Seed dormancy

The seeds of *P. oleracea* were dormant and exhibited only 27% germination without any treatment. In order to overcome seed dormancy, seeds were hydroprimed and soaked in different gibberellic acid concentrations for 24 hrs. Seeds were weighed before soaking in water or solutions of different gibberellic acid concentrations. After soaking for 24 hrs, seeds were dried at room temperature to restore their original weight before soaking treatment. Seeds were treated with different GA concentrations viz., 200, 500 and 1000 µg/ml. Stock solution of 1000 ppm was prepared by mixing GA (100 mg) in 100 ml of distilled water. Further dilution of stock solution was used to prepare other concentrations (Table 3.1).

Table 3.1: Details of preparation of different concentrations of GA.

GA concentration (µg/ml)	Stock solution of 1000 µg/ml (ml)	Distilled water (ml)
200	6	24
500	15	15
1000	30	0

3.2.3 EXPERIMENTAL TREATMENTS

For following treatments, seeds treated with 1000 ppm GA which exhibited minimum germination of 80% were used.

3.2.3.1 Light

Germination of seeds was tested by placing 20 seeds in Petri plates which were further incubated in continuous light (24 h) using light intensity of 85 m mol m^{-2} s^{-1} and dark regimes (24 h). Petri plates were enclosed in two coats of aluminium foil to completely obstruct the penetration of light. Dishes assigned to dark treatments were immediately covered after recording data.

3.2.3.2 Temperature

Seed germination was tested under seven constant temperatures viz., 20, 22, 24, 26, 28, 30 and 32°C.

3.2.3.3 Moisture stress

To determine the impact of different concentrations of moisture stress on seed germination, seeds were placed in Petri plates containing solutions of PEG 8000 and were incubated at 30°C. The equations of Michel and Kaufmann (1973) were used to prepare the solutions of PEG 8000. The PEG solutions of different water potential used were- 0, -0.1, -0.2, -0.4, -0.6, -0.8 and -1.0 MPa (Table 3.2)

Table 3.2: Details of PEG 8000 solution preparation of different concentrations

Water potential (MPa)	PEG 8000 (g/20 ml)
0	0
-0.1	1.83
-0.2	2.59
-0.4	3.66
-0.6	4.48
-0.8	5.18
-1	5.80

3.2.3.4 Salinity stress

The impact of salt stress on germination of seeds was evaluated by using various NaCl solutions of 0, 25, 50, 75, 100, 150, 200, 250 and 300 mM concentrations. The stock solution of 300 mM was prepared by dissolving 3.5 g of NaCl (MW: 58.44) in 200 ml of distilled water and then the stock solution was diluted to obtain other concentrations as given in Table 3.3.

Table 3.3: Details of preparation of different concentrations of sodium chloride (NaCl)

NaCl concentration(mM)	Stock solution of 300 mM NaCl (ml)	Distilled water (ml)
0	0	30
25	2.5	27.5
50	5	25
75	7.5	22.5
100	10	20
150	15	15
200	20	10
250	25	5

3.2.3.5 pH

To determine the effect of pH from 6.5 to 8.5 on seed germination, buffered solutions of different pH were prepared. The buffer solution of pH 6.5 was prepared by using 0.2 mM potassium hydrogen phthalate (Chachalis and Reddy 2000). 2 mM of 4-(2-hydroxyethyl) piperazine-1-ethanesulfonic acid was used to prepare buffer solutions of pH 7, 7.5 and 8 and 2 mM of tricine was used for the preparation of buffered solution of pH 8.5 (Li *et al* 2000). 0.1 M HCl or 0.1 N NaOH were used to

make final adjustment of each buffered solution. Distilled water (pH 7) was used as a control.

3.2.3.6 Burial depth

The experiment was conducted in pots of 30 cm diameter during the months of May-June 2018 when environmental conditions were optimum for seedling emergence. Each pot was filled with 8 kg soil collected from those fields which recorded no previous occurrence of this weed. The seeds were scattered on the soil surface or covered with soil to different burial depths viz., 0, 0.5, 1, 2, 3, 4 and 5 cm. The pot surface was kept moistened throughout the study period. The emergence was recorded over a period of one month. The experiment was conducted using three replicates.

3.2.3.7 Efficacy of pre-emergence herbicides: *P. oleracea* seeds were sown on the soil surface in pots of 30 cm diameter during the months of May-June 2018 when environmental conditions were optimum for seedling emergence. The influence of pre-emergence herbicides on seed germination was studied using various concentrations of different herbicides. Pre-emergence herbicides viz., pendimethalin (375, 563 and 750 g/ha), oxyfluorfen (120, 180 and 240 g/ha), oxadiargyl (45, 68 and 90 g/ha), sulfentrazone (180, 270 and 360 g/ha) and clomazone (200, 300 and 400 g/ha) were sprayed immediately after sowing using knapsack sprayer with fitted flat fan nozzle.

Treatments:

a) Pendimethalin (375, 563 and 750 g/ha)
b) Oxyfluorfen (120, 180 and 240 g/ha)
c) Oxadiargyl (45, 68 and 90 g/ha)
d) Sulfentrazone (180, 270 and 360 g/ha)
e) Clomazone (200, 300 and 400 g/ha)

3.2.4 OBSERVATIONS RECORDED

(a) Per cent germination

Number of seeds germinated were counted at interval of 24 hour till period of 15 days after the start of laboratory experiment. Visible extension of the radicle was regarded as criterion for germination.

Germination (%) = (No. of seeds germinated / total number of seeds) x 100

(b) Germination speed

Following formula was used for calculating germination speed as stated by the Association of Official Seed Analysts (1983):

$$GI = \frac{\text{Number of seeds germinated}}{\text{Days of first count}} + - - - - + \frac{\text{Number of seeds germinated}}{\text{Days of final count}}$$

(c) Mean germination time (MGT) or mean emergence time (MET)

It was calculated as stated by Ellis and Roberts (1981):

$MGT = \Sigma (Dn) / \Sigma n$

n = number of seeds germinated on day *D*

D= number of days calculated from the start of germination

(d) Growth of seedlings

Root and shoot length of seedlings were measured on 15^{th} day of germination and seedling length was expressed in centimeter.

(e) Seedling vigour index

The following formula stated by Abdul-Baki and Anderson (1973) was used to calculate seedling vigour index (SVI).

Seedling vigour Index I = seedling length (cm) x germination (%)

(f) Root to shoot length ratio (R:S)

Root to shoot length ratio was calculated as length of seedling root divided by length of seedling shoot.

(g) Emergence (%)

Emergence counts were made at an interval of 7 days for one month.

Emergence (%) = (No. of germinated seeds/ total number of seeds) x 100

(h) Weed density (No./pot)

Weed count was recorded at weekly interval for one month from each pot and density was expressed as number of plants per pot.

3.7 STATISTICAL ANALYSIS

The experiment was conducted in a completely randomized design using three replicates. The data was subjected to analysis of variance (ANOVA) using CPCS 1 software. Means were separated at $P \leq 0.05$ using Fisher's Protected Least Significant Difference (LSD) test (Cochran and Cox 1966).

CHAPTER-IV

RESULTS AND DISCUSSION

The results of present study 'Germination ecology and management of *Portulaca oleracea* L.' are presented here below:

4.1: Effect of seed priming with gibberellic acid on germination and seedling growth of *P. oleracea* L.

About 27% seeds of *P. oleracea* germinated in control. Germination percentage increased to 52% when seeds were pre-soaked in distilled water for 24 hrs. Seed soaking in gibberellic acid caused significant increase in germination as compared to control and increase in germination percentage was directly proportional to gibberellic acid concentration. Germination was increased to 82% when seeds were soaked in 1000 ppm gibberellic acid for 24 hrs. There was significant increase in germination speed due to hydropriming and gibberellic acid treatment. There was more than 3-fold and 8-fold increase in germination speed due to hydropriming and 1000 ppm gibberellic acid treatment, respectively. Seeds of *P. oleracea* started to germinate after 2 days in control but seeds either hydroprimed or treated with different concentrations of gibberellic acid were able to germinate after 24 hrs. There was decrease in mean germination time due to either hydropriming or different concentrations of gibberellic acid (Table 4.1 and Fig.4.1). Seedling vigor index was low in control. Seedling vigor index was increased due to hydropriming or seed treatment with different concentrations of gibberellic acid. There was 2-fold, 3-fold and 4-fold increase in SVI when seeds were soaked in 200, 500 and 1000 ppm gibberellic acid, respectively as compared to control (Tables 4.1-4.2 and Figs. 4.1-4.2).

Gibberellic acid is a plant growth hormone that breaks both seed coat imposed and ABA-related embryo dormancy resulting in stimulation of germination. The plant hormone abscisic acid is produced in the embryo and it inhibits the growth of embryo (Karssen *et al* 1983). Gibberellic acid is required to overcome the inhibitory effect of ABA. Debeaujon and Koornneef (2000) observed that during seed germination of *Arabidopsis*, gibberellic acid was effective in overcoming germination barriers imposed by testa and resulted in its germination. Like in present study, germination has also been reported to be stimulated in other weed species like *Avena fatua* and *Medicago radiata* by soaking seeds in gibberellic acid (Balouchi and Sanavy 2006). Cirak *et al* (2004) observed that exogenous gibberellic acid gets imbibed to seeds which stimulates endogenous gibberellic acid secretion from embryo, which further increases the synthesis of hydrolytic enzymes (α-amylase, β-amylase and maltase). These hydrolytic enzymes are transported to endosperm leading to breakdown of stored food thereby supplying energy required for seed germination. Increase in

germination percentage in hydroprimed seeds is due to imbibition, completion of pre-germination processes such as repair and synthesis of nucleic acids (DNA and mRNA) and proteins, repair of membranes and repair and synthesis of mitochondria (Bewley 1997).

Table 4.1: Effect of hydropriming and gibberellic acid on germination of *Portulaca oleracea* L.

Concentration of GA (ppm)	Germination (%)	Time to start germination (days)	Germination speed	Mean germination time (days)
Control (No treatment)	26.7±5.77	2.67±1.15	2.00±0.33	3.52±1.63
Hydropriming	51.7±2.89	1.00±0	6.72±0.63	2.10±0.20
200	60.0±5.00	1.00±0	12.00±1.00	1.00±0
500	70.0±5.00	1.00±0	15.00±1.00	1.00±0
1000	81.7±5.77	1.00±0	17.7±1.15	1.00±0
LSD (p=0.05)	9.09	0.94	1.59	1.33

Data are mean±standard deviation

Table 4.2: Effect of hydropriming and gibberellic acid on seedling growth of *Portulaca oleracea* L.

Concentration of GA (ppm)	Root length (cm)	Shoot length (cm)	Total seedling length (cm)	SVI
Control	0.32±0.03	1.12±0.02	1.44±0.05	38.13±7.22
Hydropriming	0.34±0.03	1.16±0.04	1.50±0.05	77.65±4.49
200	0.36±0.06	1.21±0.02	1.57±0.08	94.18±4.57
500	0.41±0.04	1.34±0.02	1.75±0.02	122.2±7.35
1000	0.47±0.06	1.64±0.06	2.10±0.09	171.45±5.98
LSD (p=0.05)	0.08	0.06	0.11	11.00

Data are mean±standard deviation

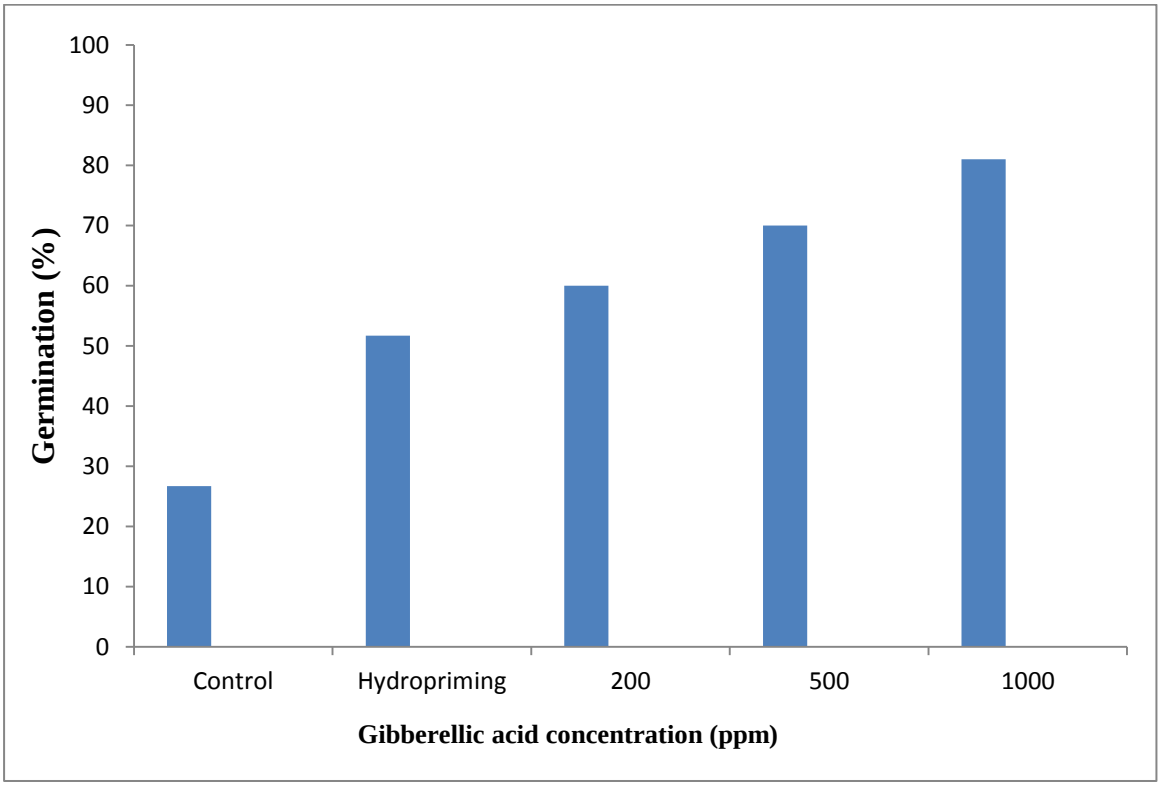

Figure 4.1: Effect of hydropriming and gibberellic acid on germination of *Portulaca oleracea* L.

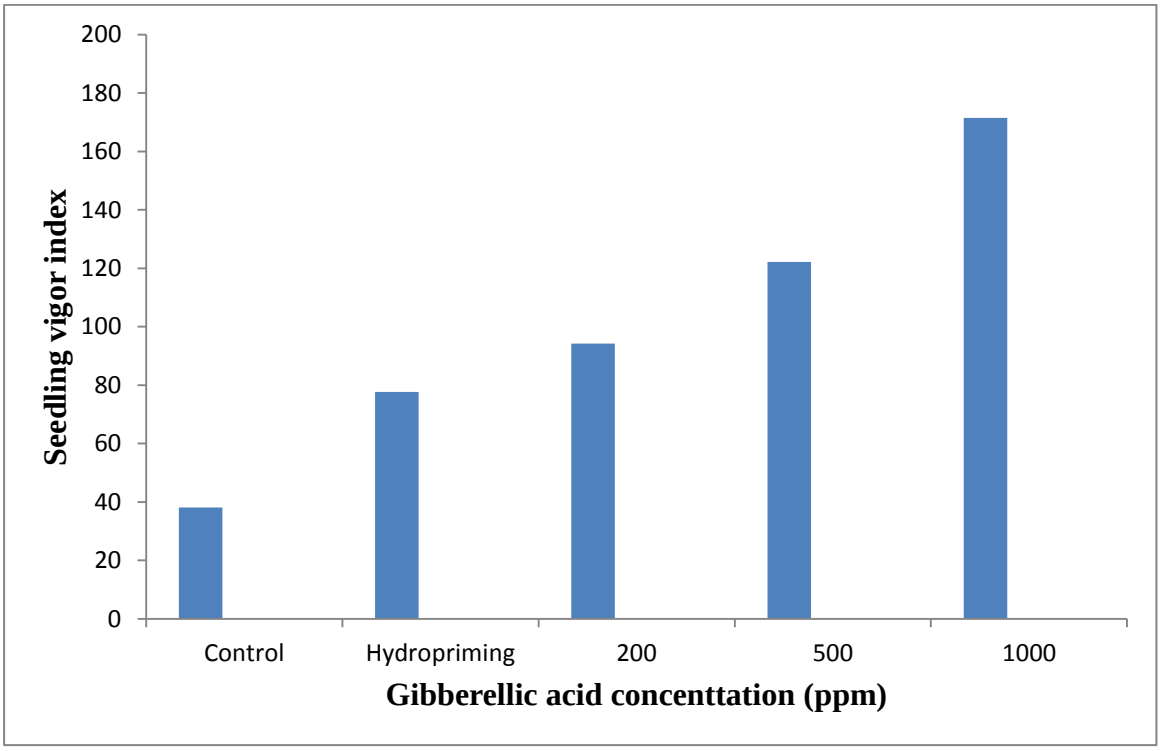

Figure 4.2: Effect of hydropriming and gibberellic acid on seedling vigor index of *Portulaca oleracea* L.

4.2: Effect of temperature on germination and seedling growth of *Portulaca oleracea* L.

There was increase in the germination percentage of seeds as the temperature was increased from 20 to 30°C. But with further increase in temperature to 32°C, there was decrease in germination. Time to start germination and mean germination time was decreased with concomitant increase in speed of germination as the temperature was increased from 20 to 30°C. Minimum time to start germination and mean germination time along with highest germination speed was recorded at 30°C. There was not much difference in germination in temperature range of 24 to 26°C; whereas steep and significant increase in germination was observed as the temperature was increased from 26 to 30°C followed by a significant decrease in germination with further increase in temperature to 32°C. Highest seedling length and seedling vigor index was also observed at 30°C (Tables 4.3 and 4.4 and Figs. 4.3 and 4.4).

Temperature is the major environmental factor that governs the emergence and timing of seed germination. Some weeds can germinate within a wide temperature range while others germinate only within a narrow temperature range. Temperature is essential factor that regulates germination as both upper and lower limits of temperature are usually related with release of dormancy and initiation of seed germination (Kruk and Benech-Arnold 2000). Some weeds can germinate only within narrow temperature range eg. *Lathyrus aphaca* and *Vicia sativa.* Tanveer *et al* (2012) observed that optimum temperature for *Lathyrus aphaca* and *Vicia sativa* is 15-20°C, with maximum germination of *Lathyrus aphaca* (92%) at 15°C and of *Vicia sativa* (85%) at 20°C. Weeds that germinate within wide range of temperature are *Eupatorium adenophorum* (43 to 93% in temperature range of 10-30°C), *Dactyloctenium aegyptium* (10 to 43% in temperature range of 15-40°C) and *Desmodium tortuosum* (1 to 81.3% in temperature range of 15/10 to 45/35°C) (Lu *et al* 2006, Burke *et al* 2003 and Singh and Singh 2009). Although, these weeds germinated within a wide range of temperature but exhibited maximum germination at a particular temperature i.e. 25, 30 and 30/20°C for *Eupatorium adenophorum, Dactyloctenium aegyptium* and *Desmodium tortuosum,* respectively. Chauhan and Johnson (2009) observed that population of *Portulaca oleracea* from Los Banos, Philippines was able to germinate (70 to 81%) in wide range of temperature i.e. 25/15 to 35/25°C, with maximum germination at 30/20°C. The North-Indian population of *P.oleracea* used in this study could also germinate (18-88%) in wide temperature range of 20-32°C, but exhibited maximum germination at 30°C. The

population of *P. oleracea* from London exhibited 96% germination under fluctuating light/dark temperature of 35/20°C; but germination was reduced to 15% at 25/10°C (Miyanishi and Cavers 1980). Temperature data recorded by School of Climate Change and Agricultural Meteorology, College of Agriculture, Punjab Agricultural University, Ludhiana during 2016-2018 indicates that temperature during months of April to October is favourable for germination of this weed with average temperature in the range of 24.2 to 33.7°C. But maximum emergence can be expected during months of June to August as along with favourable temperature during these months (28.0-32.4°C), sufficient moisture is also available during these months due to rainfall (Table 4.5). Moreover, it emerges as a major weed in vegetable fields in which adequate moisture levels are maintained by frequent irrigation, so it may emerge in multiple flushes depending upon the prevailing ambient temperature.

Table 4.3: Effect of temperature on germination of *Portulaca oleracea* L. (24 hrs photoperiod)

Temperature (°C)	Germination (%)	Time to start germination (days)	Germination speed	Mean germination time (days)
20	18.33±7.64	10.0±0	0.43±0.06	10.8±0.59
22	38.33±5.77	10.0±0	0.88±0.12	10.0±0
24	51.67±2.89	8.0. ±0	1.09±0.04	8.7±0.31
26	53.33±2.89	6.0±0	2.21±0.40	5.0±0.40
28	78.33±2.89	5.0±0	3.13±0.23	5.0±0
30	88.33±7.64	1.0±0	17.67±2.31	1.0±0
32	53.33±5.77	2.0±0	4.72±0.25	2.4±0.35
LSD (p=0.05)	9.55	0.1×10^{-5}	1.57	0.56

Data are mean±standard deviation

Table 4.4: Effect of temperature on seedling growth of *Portulaca oleracea* L. (24 hrs photoperiod)

Temperature (°C)	Root length (cm)	Shoot length (cm)	Total seedling length (cm)	SVI
20	0.19±0.01	0.88±0.11	1.08±0.10	19.62±8.43
22	0.22±0.04	1.32±0.15	1.55±0.12	59.23±9.25
24	0.29±0.04	1.51±0.09	1.80±0.05	93.25±7.43
26	0.35±0.07	1.56±0.08	1.91±0.03	101.65±4.67
28	0.41±0.07	1.57±0.09	1.98±0.04	154.92±8.80
30	0.49±0.03	1.76±0.10	2.25±0.10	198.10±10.90
32	0.36±0.06	1.53±0.10	1.89±0.15	100.87±11.94
LSD (p=0.05)	0.09	0.2	0.16	15.84

Data are mean±standard deviation

Table 4.5: Data of maximum, minimum and average temperature (°C) and rainfall (mm) at Ludhiana during the years 2016-2018

YEAR	2016			2017			2018			2016	2017	2018
Month	Max. Temp	Min. Temp	Mean	Max. Temp	Min. Temp	Mean	Max. Temp	Min. Temp	Mean	Rainfall (mm)	Rainfall (mm)	Rainfall (mm)
January	17.2	7.4	12.3	18.2	7.6	12.9	18.7	6.2	12.5	19.4	46.1	18.4
February	23	9	16	23.1	9.3	16.2	22.8	9.1	16	8.8	5.2	27
March	28	14.6	21.3	27.2	12.5	19.9	29.3	13.1	21.6	41.1	40.8	0
April	36.6	19.6	28.1	36.9	20	28.5	35.8	19.9	27.8	3.0	14.8	10
May	39.6	24.6	32.1	38.8	25.1	32	39.1	24.1	31.6	25.2	31.6	19
June	39.8	28.5	33.7	36.7	26.2	31.5	37.6	27.6	32.4	86	127	141.8
July	33.5	27.3	30.4	34.6	27.5	31.3	34.3	26.6	32.4	305.5	112	376.6
August	33.3	26.2	29.7	33.9	26.7	30.3	34.1	27.3	30.7	87.6	131.4	74
September	34	25.5	29.7	33.7	23.9	28.8	32.1	24	28	15	25.4	250.6
October	32.7	19	25.9	33.3	18.5	25.9	31.3	17.1	24.2	20	0	0
November	27.7	12	19.9	24.7	11.5	18.1	26.8	11.8	19.3	02	7	26
December	22.2	8.6	15.4	20.9	7.5	14.2	20.6	5.5	13.1	0	24	0

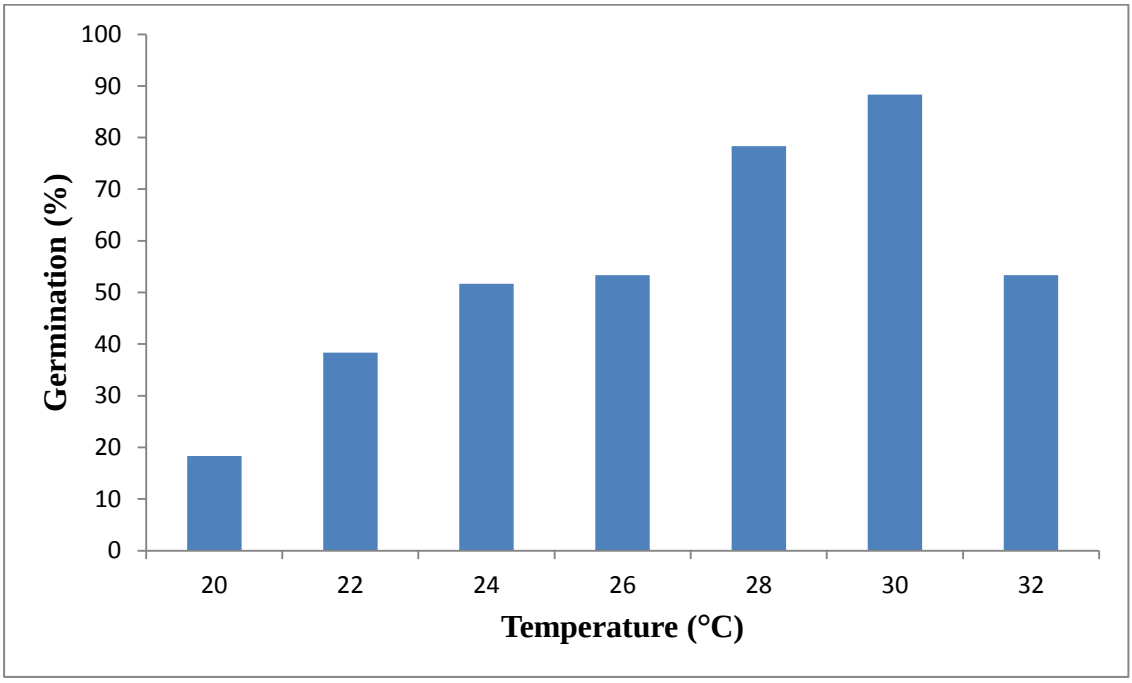

Figure 4.3: Effect of temperature on germination of *Portulaca oleracea* L. (24 hrs photoperiod)

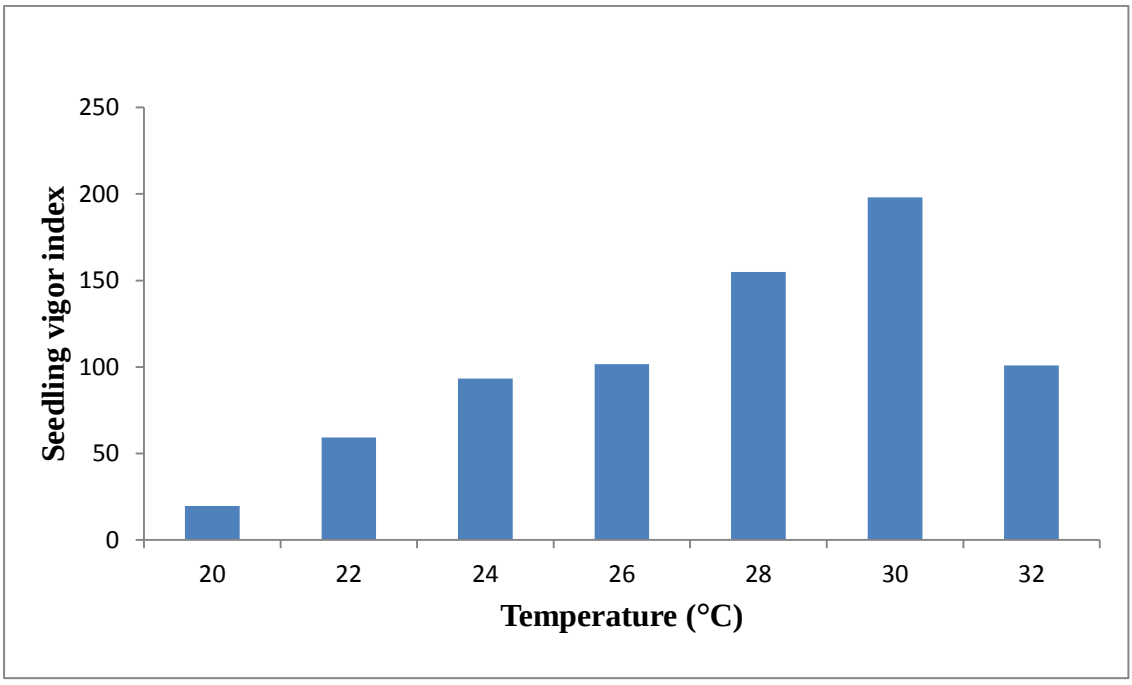

Figure 4.4: Effect of temperature on seedling vigor index of *Portulaca oleracea* L. (24 hrs photoperiod)

4.3: Effect of light on germination of *Portulaca oleracea* L.

Light has significant effect on germination of *P. oleracea* as higher germination percentage was observed in light as compared to dark at all the tested temperatures. However, seeds were able to germinate in complete darkness. In presence of light, germination increased from 18.33 to 53.33% with increase in temperature from 20 to 26°C and maximum germination was observed at 30°C (88.33%). However, in dark germination increased from 6.7 to 25% with rise in temperature from 20 to 26°C and maximum germination (73.33%) was observed at 30°C. This indicates that although light is not necessary for germination of *P. oleracea* seeds but it somehow stimulates the germination (Table 4.6 and Fig.4.5).

Light acts as a soil depth indicator, inducing higher germination of seeds present on or near the soil surface than the seeds buried deep in the soil. Seeds that germinate in presence of light are positively photoblastic while negatively photoblastic seeds are those whose germination is inhibited in presence of light; whereas some seeds are non-photoblastic as light do not affect their germination. At 30°C, 95% seeds of *Leptochloa chinensis* germinated in light, but in dark germination was reduced to 20%, indicating that germination is highly induced by light (Benvenuti *et al* 2004). The effect of light on germination of *L. chinensis* is phytochrome-mediated and according to last type of irradiation received by seeds, photochemical reactions tend to stabilize phytochrome in its active or inactive form. Red-light irradiation of seeds promoted seed germination; whereas irradiation of seeds by far-red light inhibited the seed germination in *L. chinensis*. Chauhan and Johnson (2009) observed that germination of *P. oleracea* population from Los Banos, Philippines was stimulated by light at all tested temperatures viz., 25/15, 30/20 and 35/25°C, with 70, 81 and 75% germination, respectively. However, only 1% seeds germinated in dark at all temperatures (25/15, 30/20 and 35/25°C). Germination of *Urena lobata* was stimulated by light with 65% germination at 30/20°C in light and 46% germination in dark at 30/20°C (Awan *et al* 2014). Germination of *U. lobata* seeds in both light and dark indicates that light is not necessary for germination and seed can germinate when buried too deep. However, due to small seed size (2 mm diameter) seedling emergence was observed to be low from deeper soil layers. In present study, we observed considerable germination (73.3%) of *P. oleracea* at 30°C even in dark which indicates that light is not a pre-requisite for seed germination and thus seeds could emerge from deeper soil depth. However, due to small seed size (1000 seed weight=1.40 g), only very less emergence could be expected under field conditions from deeper soil layers, due to the presence of only limited storage reserves in the seeds of this weed which would

be insufficient to support the emergence of seedlings from greater soil depths. Thus, weeds like *U. lobata*, *P. oleracea* whose germination is independent of light can emerge under tree and crop canopies in non-cropped and cropped areas, respectively.

Table 4.6: Effect of light on germination of *Portulaca oleracea* L.

Temperature (°C)	Germination (%)	
	Light	Dark
20	18.33±7.64	6.67±2.89
22	38.33±5.77	16.67±5.77
24	51.67±2.89	16.67±2.89
26	53.33±2.89	25.00±10
28	78.33±2.89	28.33±11.55
30	88.33±7.64	73.33±5.77
32	53.33±5.77	20±10
LSD (p=0.05)	9.55	13.51

Data are mean±standard deviation

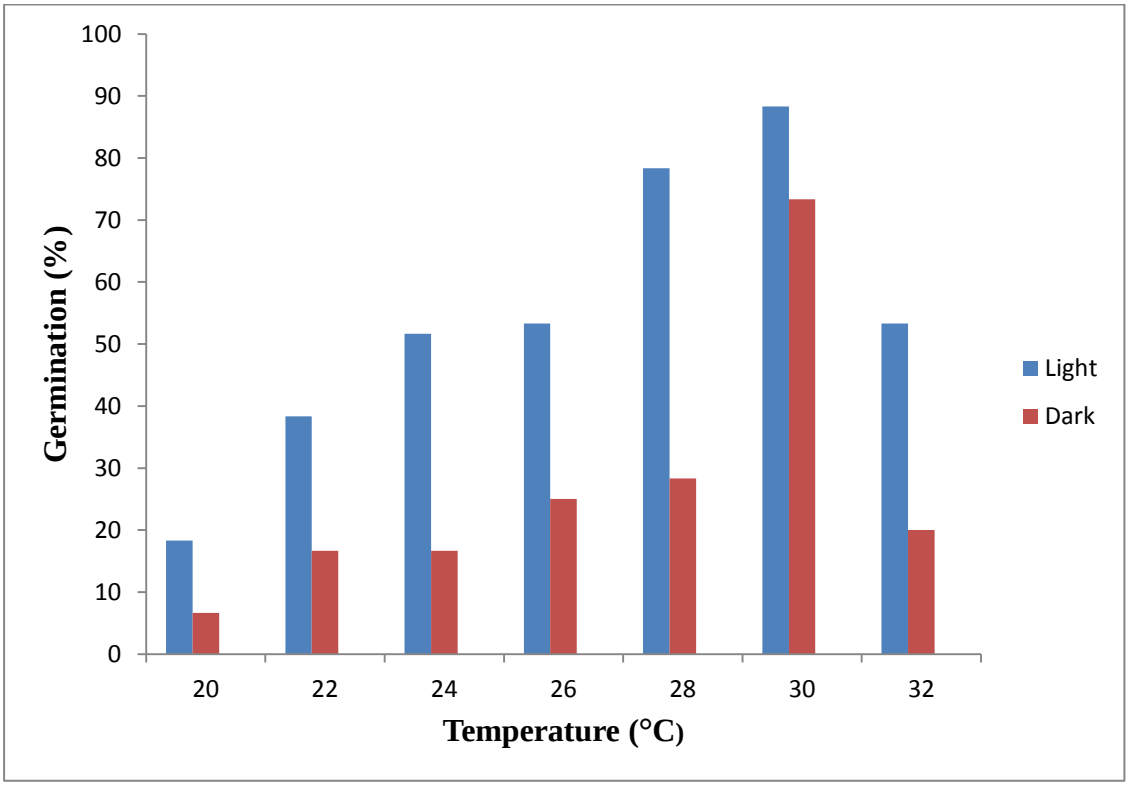

Figure 4.5: Effect of light on germination of *Portulaca oleracea* L.

4.4: Effect of salinity on germination and seedling growth of *Portulaca oleracea* L.

There was significant decrease in germination, germination speed and seedling vigor index with concomitant increase in time to start germination and mean germination time with the increase in NaCl concentration. However, seeds exhibited significant reduction in germination when concentration of NaCl was increased in the germination media above 50 mM. Maximum germination and seedling vigor index were observed in control. Germination was completely inhibited at 300 mM NaCl (Tables 7-8 and Figs. 4.6-4.8). Germination was inhibited by 50% at 163.56 mM NaCl concentration (Fig. 4.9). There was 33.3 per cent points reduction in germination at 150 mM NaCl as compared to control. Mean germination time and time to start germination was increased by 3.3-fold and 4-fold, respectively at 150 mM NaCl as compared to their controls. Seedling vigor index I was reduced by 77% as compared to control at 150 mM NaCl concentration. Maximum root to shoot length ratio (R:S) was observed in control and significant decrease was observed in this ratio with at 75 mM NaCl or higher concentrations indicating higher inhibitory effect of NaCl on root growth as compared to shoot growth (Table 4.8).

Salinity is a key factor that affects seed germination and seedling growth. Harmful effects caused by high salinity are ion toxicity, oxidative stress, alteration of metabolic processes, reduction of cell division and expansion and membrane disorganization (Sidari *et al* 2008). High salinity prevents water from entering the seed and thereby inhibits seed germination. High concentration of Na^+ and Cl^- ions in the cells inhibit the metabolism of dividing and expanding cells, thereby retarding the seed germination. When plant cells are exposed to salts, it results in inhibition of water uptake, cell expansion (Munns and Tester 2008). Chauhan and Johnson (2009) observed that population of *P. oleracea* from Los Banos, Philippines can germinate under NaCl concentration from 0 to 200 mM. The present study show that North-Indian population of *P. oleracea* used in this study has higher salinity tolerance than its population from Philippines and exhibited about 17% germination even at 250 mM NaCl. Germination of *P. oleracea* population from Philippines was completely inhibited at 250 mM NaCl; whereas complete inhibition of seed germination in this North-Indian population occurred at 300 mM. The ability of *P. oleracea* to germinate under high NaCl concentrations (25-250 mM) indicate that this weed can be problematic weed even in salt affected areas of Punjab such as Sri Muktsar Sahib, Faridkot, Bathinda and Sangrur (Shakya and Singh 2010). Germination of *P. oleracea* population from Philippines and North-India was

reduced by 50% at 106 and 163.56 mM NaCl concentration, respectively. NaCl concentration which caused 50% inhibition of germination in other summer weeds infesting vegetable crops are 77.5, 194, 66 and 112 mM NaCl for *Eleusine indica, Eclipta prostrata, Digitaria longiflora* and *Digitaria ciliaris,* respectively (Chauhan and Johnson 2008a, Chauhan and Johnson 2008b, Chauhan and Johnson 2008c). This indicates that *P. oleracea* has higher ability to tolerate salinity than *Eleusine indica, Digitaria longiflora* and *Digitaria ciliaris* but less tolerant as compared to *Eclipta prostrata.*

Table 4.7: Effect of NaCl on germination of *Portulaca oleracea* L.

NaCl concentration (mM)	Germination (%)	Time to start germination (days)	Germination speed	Mean germination time (days)
0 (Control)	85.0±10.00	1.00±0	13.36±3.25	1.42±0.32
25	83.3±7.64	1.00±0	13.09±3.39	1.43±0.45
50	80.0±5.00	3.00±0	4.79±0.66	2.85±0.74
75	73.3±5.77	3.00±0	4.23±0.42	3.66±0.17
100	58.3±7.64	4.00±0	2.67±0.47	4.54±0.42
150	51.7±2.89	4.00±0	2.27±0.12	4.63±0.45
200	30.0±5.00	4.67±1.15	1.22±0.39	5.14±0.79
250	16.7±7.64	6.00±0	0.54±0.27	6.17±0.29
300	0	0	0	0
LSD (p=0.05)	10.94	0.66	2.75	0.80

Data are mean±standard deviation

Table 4.8: Effect of NaCl on seedling growth of *Portulaca oleracea* L.

NaCl concentration (mM)	Root length (cm)	Shoot length (cm)	Root to shoot length ratio (R:S)	Total seedling length (cm)	SVI
0 (Control)	0.64±0.05	0.81±0.09	0.80±0.06	1.45±0.13	122.62±10.45
25	0.61±0.16	0.70±0.10	0.88±0.24	1.31±0.20	108.07±10.43
50	0.46±0.09	0.54±0.03	0.86±0.14	1.00±0.10	80.32±9.99
75	0.26±0.04	0.47±0.05	0.56±0.02	0.74±0.09	53.77±3.94
100	0.16±0.04	0.41±0.05	0.40±0.04	0.57±0.09	33.15±5.91
150	0.15±0.04	0.39±0.06	0.39±0.04	0.55±0.10	28.15±4.38
200	0.11±0.02	0.32±0.03	0.36±0.08	0.43±0.03	13.08±2.93
250	0.10±0	0.26±0.01	0.39±0.04	0.36±0.01	5.97±2.79
300	0	0	0	0	0
LSD (p=0.05)	0.11	0.10	0.18	0.18	11.48

Data are mean±standard deviation

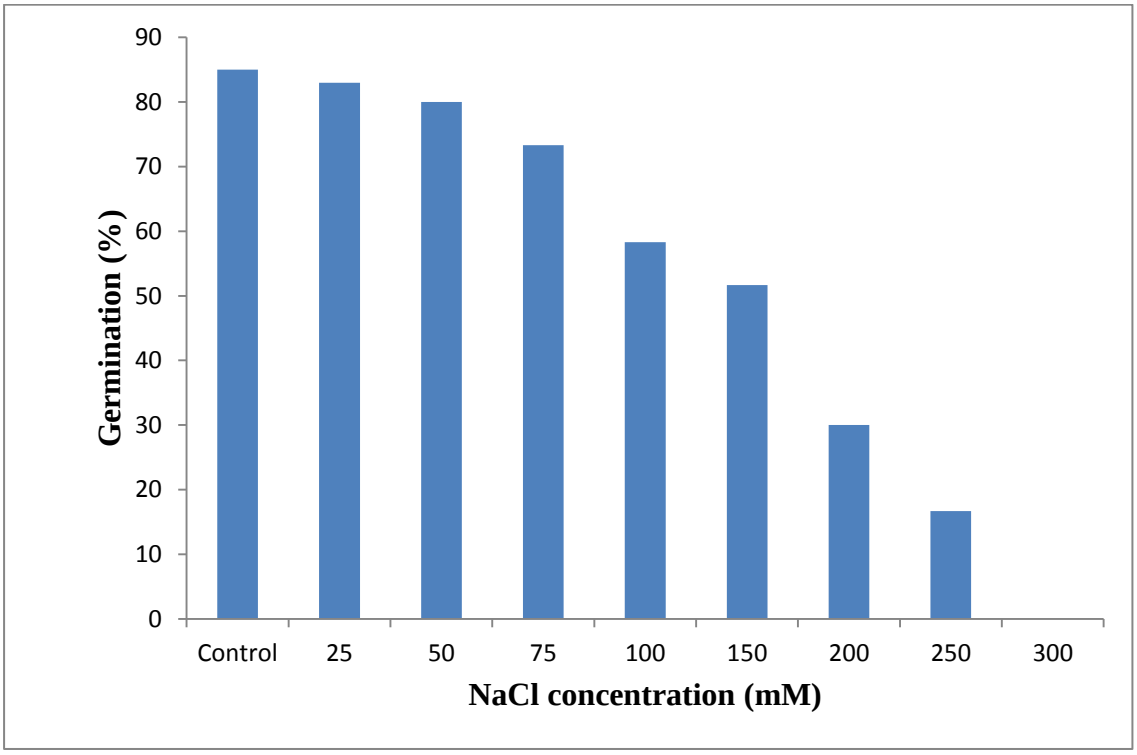

Figure 4.6: Effect of NaCl on germination of *Portulaca oleracea* L.

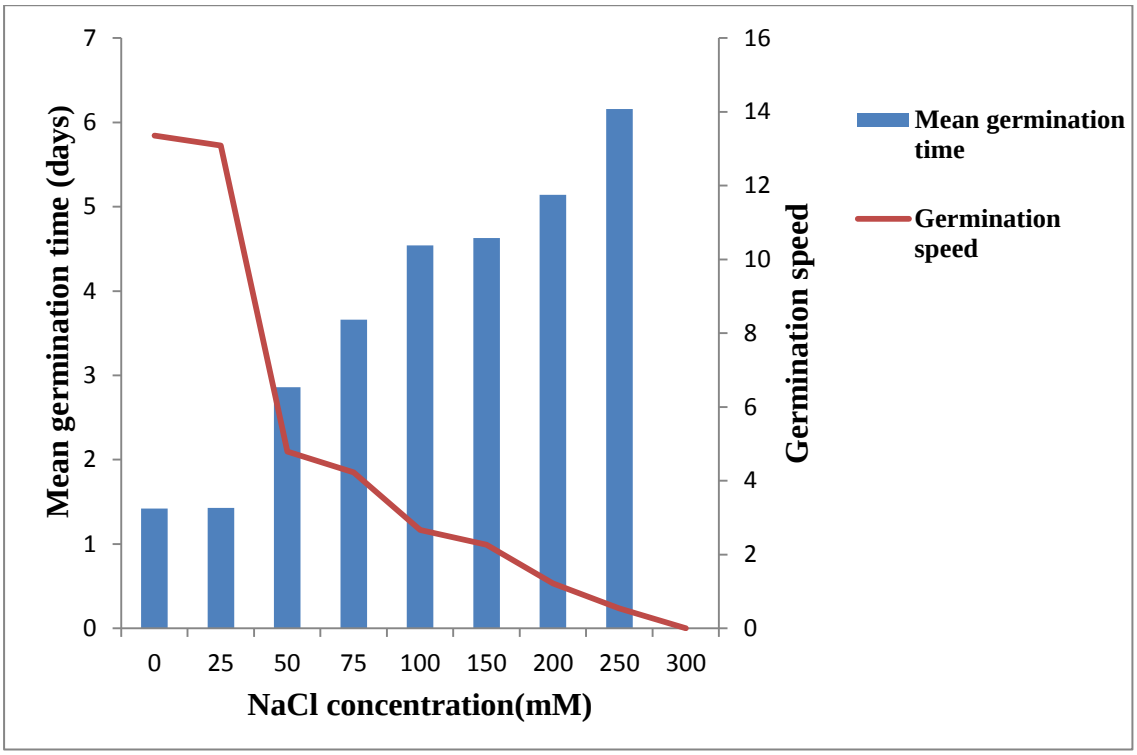

Figure 4.7: Effect of NaCl on mean germination time and germination speed of *Portulaca oleracea* L.

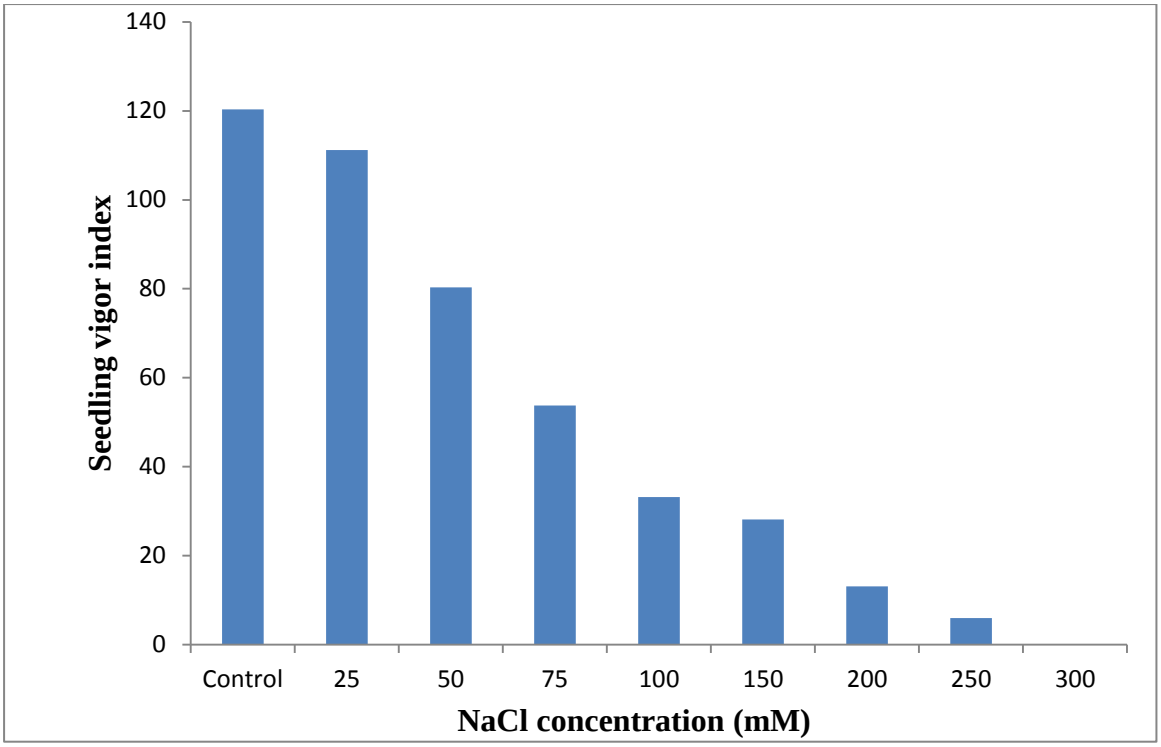

Figure 4.8: Effect of NaCl on seedling vigor index of *Portulaca oleracea* L.

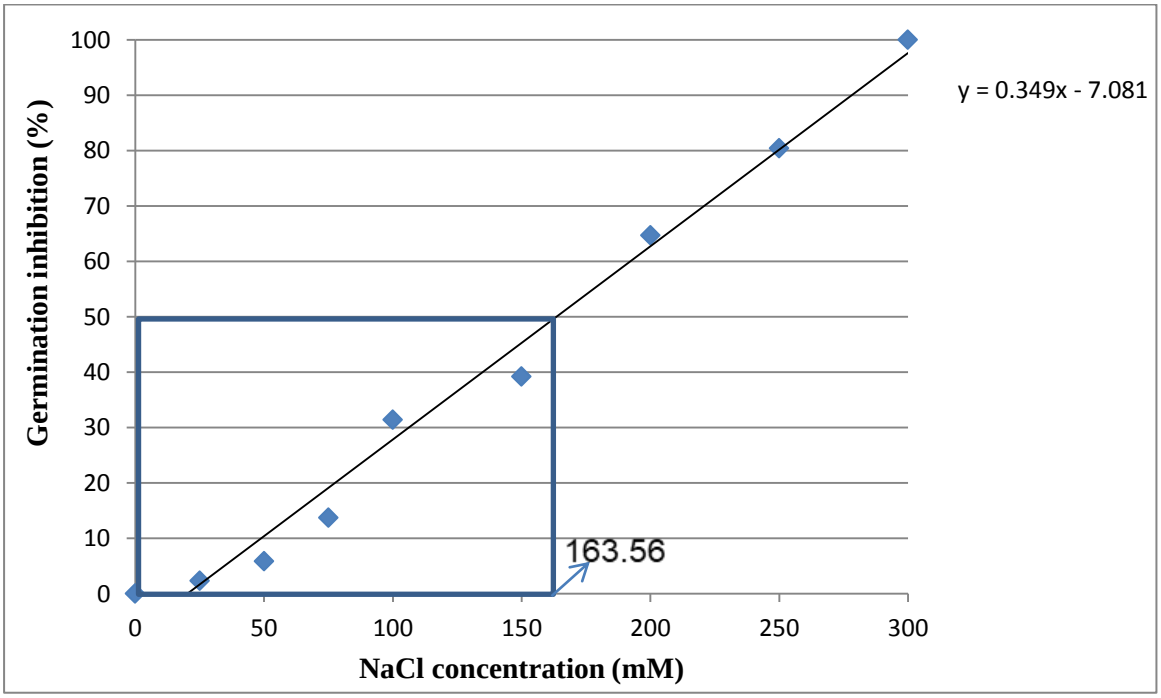

Figure 4.9: NaCl concentration required for 50% inhibition of germination in *Portulaca oleracea* L.

4.5: Effect of pH on germination and seedling growth of *Portulaca oleracea* L.

There was significant effect of pH on the germination and seedling growth of *Portulaca oleracea*. Maximum germination and speed of germination were observed in control; and a decrease in these parameters was observed with either increase or decrease in pH (Table 4.9 and Figs. 4.10-4.11). However, more than 50% germination was observed in pH range of 6.5-8. Germination was decreased by about 36.7 per cent points at pH 8 as compared to control (pH 7.0). Although decrease in germination and seedling vigor index was observed when pH was increased from 7 to 7.5 but no considerable difference was observed in these parameters with further increase in pH to 8.0 (Table 4.10 and Fig. 4.12). Minimum time to start germination was recorded in control and 3-fold increase in time to start germination was recorded at all other tested pH. Germination speed was decreased by 3.8-fold with increase in pH from 7 to 8.0 as compared to control. Seedling vigor index was observed to be maximum in control and a decrease was observed at pH <7 or >7. There was 71.6% reduction in seedling vigor index at pH 8 as compared to its control. Maximum root to shoot length ratio (R:S) was observed at pH 7.0. There was decrease in R:S with either increase or decrease in pH, although the differences were statistically non-significant (Table 4.10).

Soil pH is considered to be a key factor affecting seed germination and plant growth. The study conducted by Singh and Benbi (2016) reported that soils of Punjab are moderately alkaline. 9% of Punjab farms have neutral soil pH (6.6-7.5) and 87% farms have alkaline soil pH (> 7.5). Acidic soil (pH < 7) causes aluminium and manganese toxicity, low nitrogen supply, phosphorus deficiency and toxic concentrations of phenolic acids which lead to low germination and poor plant growth (Barcelo *et al* 1996, Foy 1984 and Baziramakenga *et al* 1995). Increased activity of H^+ ion in acidic soil affects ion transport mechanisms across cell membranes. In alkaline soil (pH >7) availability of phosphorus and micronutrients is reduced and this leads to poor germination (Gentili *et al* 2018). Chauhan and Johnson (2009) observed that 70% seeds of *Portulaca oleracea* (population of Philippines) germinated in pH range of 5-9; but in present study, there was decrease in germination of *P. oleracea* from 88.33 to 46.67% with increase in pH from 7 to 8.5. Chauhan and Johnson (2008a) recorded 92 to 95% germination of *Eleusine indica* in pH range of 5 to 10, indicating that pH is not a limiting factor for this weed. The experiment conducted by Chauhan and Johnson (2008b) reported that *Eclipta prostrata* was able to germinate (87-93%) over pH range of 4 to 10, signifying that this weed can germinate over wide pH range. Burke *et al* (2003) recorded that *Dactyloctenium aegyptium* was sensitive to pH as greater germination

(60%) was observed at pH 4 and germination decreased to only 5% with increase in pH to 9. The results of present study indicated drastic reduction in germination of *P. oleracea* at alkaline pH (7.5-8.5) while it exhibited relatively higher germination acidic pH (pH 6.5). It shows its higher ability to tolerate acidic conditions than alkaline for germination and early seedling growth. Kovacevic and Bukovac (1974) also reported ability of *P. oleracea* to grow in acidic soils.

Table 4.9: Effect of pH on germination of *Portulaca oleracea* L.

pH	Germination (%)	Time to start germination (days)	Germination speed	Mean germination time (days)
6.5	71.7±5.77	3.0±0	4.39±0.34	3.50±0.10
7.0 (Control)	88.3±5.77	1.0±0	11.60±0.26	2.32±0.19
7.5	51.7±10.41	3.0. ±0	3.00±0.50	3.76±0.35
8.0	51.7±2.89	3.0±0	3.05±0.48	3.36±0.63
8.5	46.7±5.77	3.0±0	2.72±0.10	3.30±0.52
LSD (p=0.05)	11.26	0.18×10^{-5}	0.67	0.74

Data are mean±standard deviation

Table 4.10: Effect of pH on seedling growth of *Portulaca oleracea* L.

pH	Root length (cm)	Shoot length (cm)	Root to shoot length ratio (R:S)	Total seedling length (cm)	SVI
6.5	0.18±0.05	0.73±0.12	0.25±0.09	0.91±0.10	64.92±4.88
7.0 (Control)	0.47±0.06	1.27±0.10	0.37±0.02	1.74±0.16	153.50±11.51
7.5	0.18±0.02	0.69±0.10	0.26±0.04	0.87±0.07	44.60±7.32
8.0	0.18±0.04	0.67±0.12	0.28±0.10	0.84±0.10	43.67±6.60
8.5	0.14±0.02	0.56±0.10	0.26±0.03	0.70±0.10	32.67±6.43
LSD (p=0.05)	0.07	0.19	NS	0.20	13.96

Data are mean±standard deviation

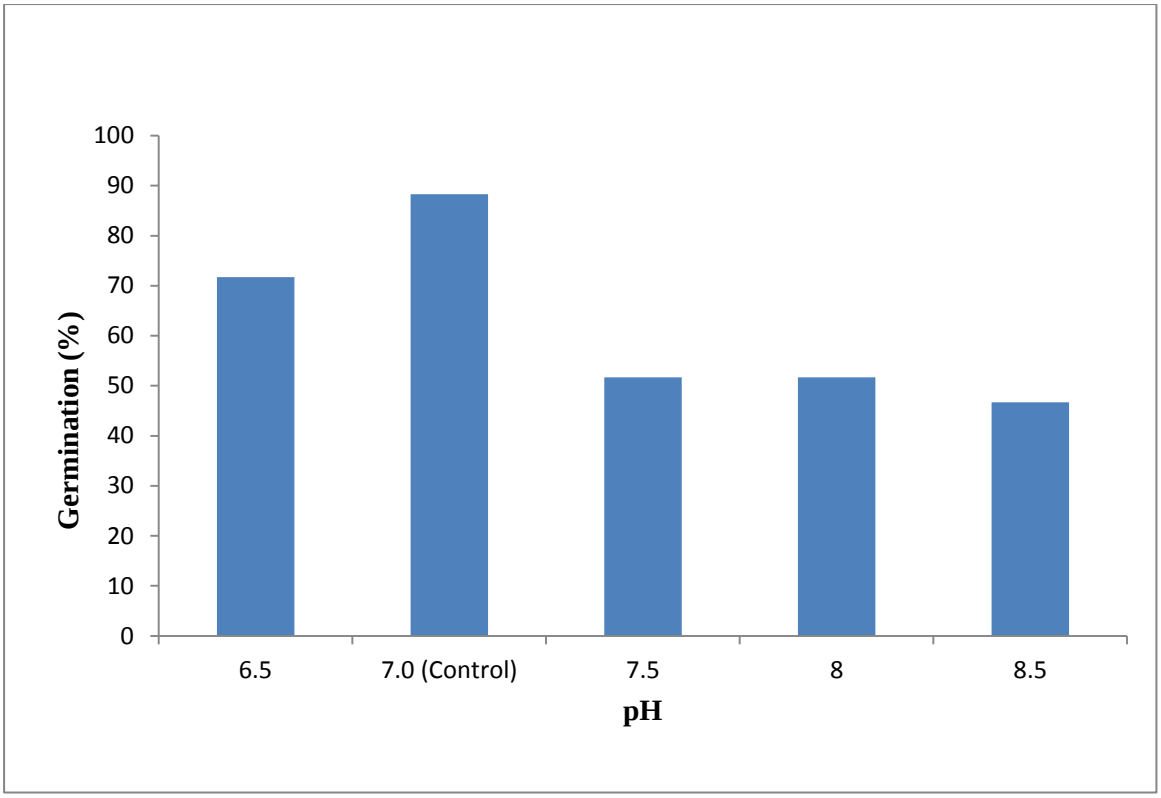

Figure 4.10: Effect of pH on germination of *Portulaca oleracea* L.

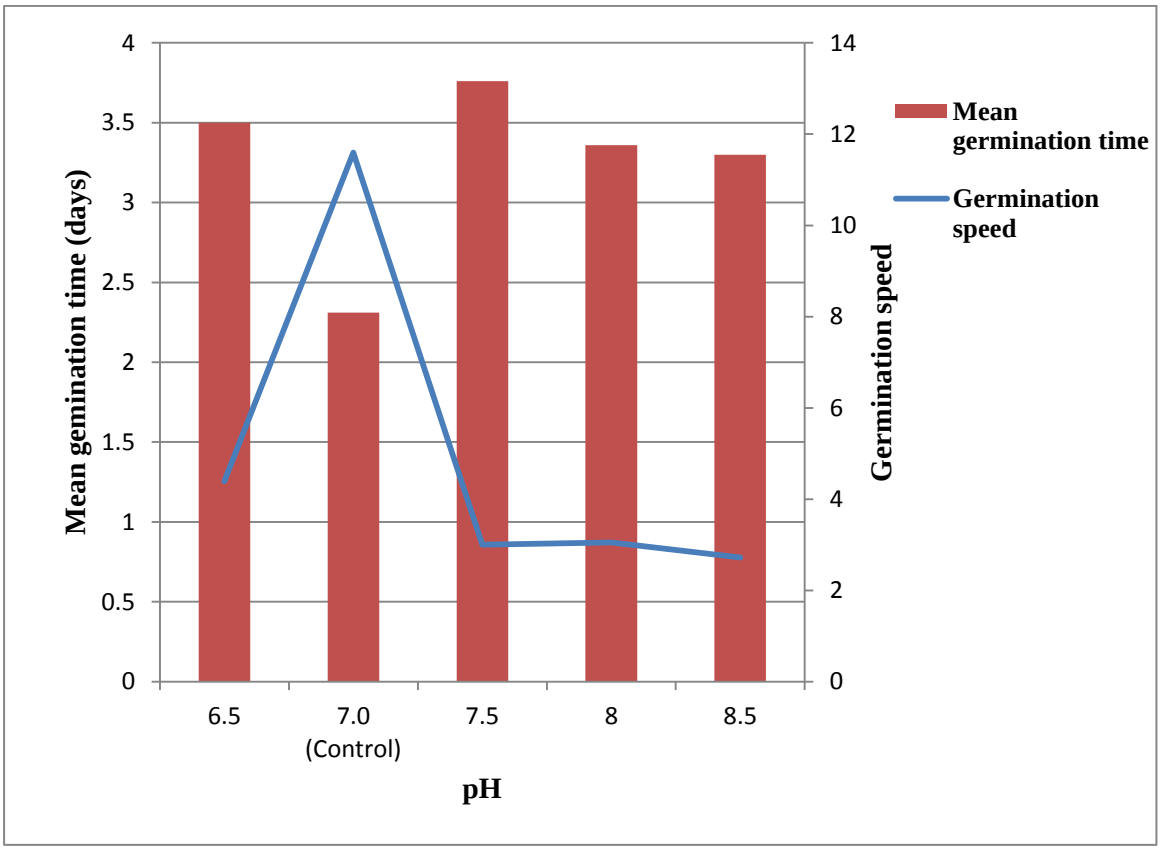

Figure 4.11: Effect of pH on mean germination time and germination speed of *Portulaca oleracea* L.

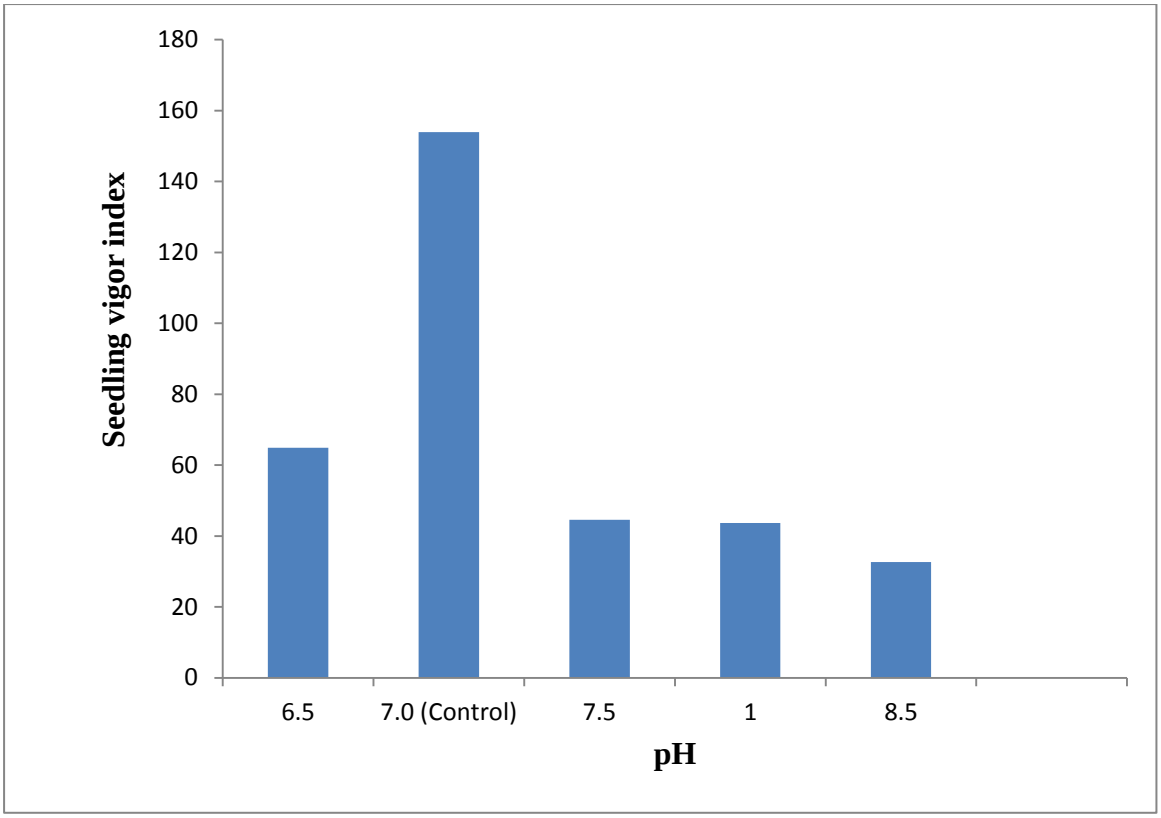

Figure 4.12: Effect of pH on seedling vigor index of *Portulaca oleracea* L.

4.6: Effect of moisture stress on germination and seedling growth of *Portulaca oleracea* L.

The seeds of *P. oleracea* were very sensitive to moisture stress as germination decreased with decrease in osmotic potential and germination was completely suppressed at -1.0 MPa (Fig. 4.13). There was decrease in germination speed with concomitant increase in time to start germination and mean germination time when moisture stress was increased from -0.1 to -0.8 MPa (Table 4.11 and Figs 4.13-4.14). Germination was decreased by 40 per cent points and time to start germination was increased by 5.3-fold at -0.6 MPa as compared to their respective controls. Germination was inhibited by 50% at osmotic potential of -0.51 MPa (Fig. 4.15). The highest seedling length was recorded in control and increase in moisture stress significantly reduced seedling length. At -0.6 MPa, seedling vigor index was reduced by 70% than control (Table 4.12 and Fig.4.14). Maximum root to shoot length ratio (R:S) was observed in control. There was significant decrease in R:S at osmotic potential of -0.6 and -0.8 MPa indicating higher inhibitory effect of moisture stress on root growth as compared to shoot growth (Table 4.12).

Moisture is an essential abiotic factor responsible for imbibition of seeds and germination of seeds. Water is required for activating enzymes responsible for translocation of stored reserves in seed to make them available to germinating

embryo. Intially, water transport in seed is through apoplast which is independent of osmotic potential of surrounding environment. Later, seed cells are involved in water movement (symplast) and difference between the water potential of the seed and environment is essential for water movement. Water flux inside the seed decreases as the water potential in the surrounding environment decreases, until the water diffusion through symplast is stopped. This directly affects both germination percentage and germination rate (Souza and Cardoso 2000). Large molecular mass of polyethylene glycol prevents entry of this chemical into the seed and it is metabolically inactive; therefore it is the most preferred chemical for simulating moisture stress conditions under controlled conditions in the laboratory (Berkat and Briske 1982, Hohl and Peter 1991). Chauhan and Johnson (2008a) recorded sharp decline in germination of *Eleusine indica* from 92 to 5% with decrease in osmotic potential from 0 to -0.6 MPa and germination was completely inhibited at -0.8 MPa. Chauhan and Johnson (2009) recorded that germination of *Portulaca oleracea* decreased from 71 to 10% with decrease in osmotic potential from 0 to -0.6 MPa; and germination was completely suppressed at -0.8 MPa. In present study, *P. oleracea* seeds exhibited 12% germination at -0.8 MPa and no germination was recorded at -1.0 MPa. This indicates relatively higher ability of this North-Indian population of *P. oleracea* to tolerate moisture stress as compared to its population from Philippines. However, both the population had less than 50% germination at -0.6 MPa suggesting that this weed requires moist environment to germinate. Chauhan (2011) reported that germination of *Dactyloctenium aegyptium* declinded from 90 to 9% as osmotic potential decreased from 0 to -0.6 MPa and germination was completely inhibited at -0.8 MPa. The experiment conducted by Chauhan and Johnson (2008a) recorded sharp decrease in germination of *Eleusine indica* from 92 to 5% as osmotic potential decreased from 0 to -0.6 MPa and germination was completely inhibited at osmotic potential of -0.8 MPa. Tanveer *et al* (2013) observed that germination of *Trianthema portulacastrum* decreased from 100 to 20% with decrease in osmotic potential from 0 to -0.8 MPa and germination was completely inhibited at -1.0 MPa. Osmotic potential required for inhibiting 50% germination of summer weeds infesting vegetable crops is -0.23, -0.4 and -0.57 MPa for *Dactyloctenium aegyptium, Eleusine indica* and *Trianthema portulacastrum,* respectively (Chauhan 2011, Chauhan and Johnson 2008a, Tanveer *et al* 2013). This indicates that germination of *D. aegyptium* and *E. indica* is more sensitive to moisture stress as compared to *P. oleracea* while *T. portulacastrum* has comparatively higher ability to tolerate moisture stress.

Table 4.11: Effect of moisture stress on germination of *Portulaca oleracea* L.

Osmotic potential (MPa)	Germination (%)	Time to start germination (days)	Germination speed	Mean germination time (days)
Control	85.0±5.00	1.00±0	15.72±1.78	1.30±0.22
-0.1	75.0±5.00	1.00±0	10.17±0.72	1.97±0.05
-0.2	66.7±2.89	3.00±0	3.31±0.07	4.39±0.32
-0.4	55.0±5.00	4.00±0	2.24±0.31	5.11±0.29
-0.6	45.0±5.00	5.33±1.53	1.68±0.53	5.76±1.52
-0.8	11.7±2.89	7.00±0	0.32±0.06	7.22±0.39
-1.0	0	0	0	0
LSD (p=0.05)	7.15	1.01	1.33	1.08

Data are mean±standard deviation

Table 4.12: Effect of moisture stress on seedling growth of *Portulaca oleracea* L.

Osmotic potential (MPa)	Root length (cm)	Shoot length (cm)	Root to shoot length ratio (R:S)	Total seedling length (cm)	SVI
Control	0.71±0.04	0.81±0.09	0.88±0.05	1.51±0.13	128.25±6.44
-0.1	0.57±0.08	0.73±0.03	0.78±0.11	1.31±0.09	97.98±8.95
-0.2	0.53±0.03	0.67±0.08	0.80±0.08	1.20±0.09	80.13±9.10
0.4	0.48±0.04	0.57±0.08	0.85±0.07	1.04±0.11	57.75±11.25
-0.6	0.33±0.07	0.53±0.03	0.62±0.13	0.86±0.08	38.88±5.65
-0.8	0.22±0.13	0.39±0.06	0.53±0.24	0.61±0.19	7.10±2.48
-1.0	0	0	0	0	0
LSD (p=0.05)	0.12	0.11	0.21	0.19	12.71

Data are mean±standard deviation

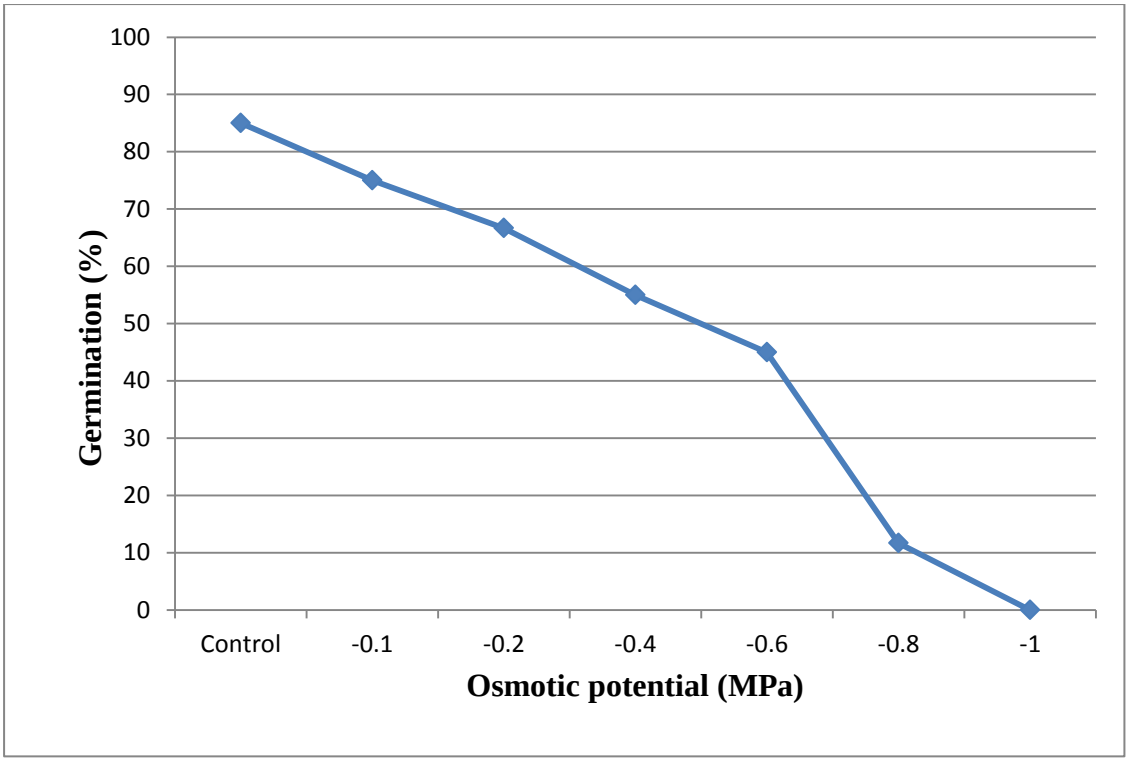

Figure 4.13: Effect of moisture stress on germination of *Portulaca oleracea* L.

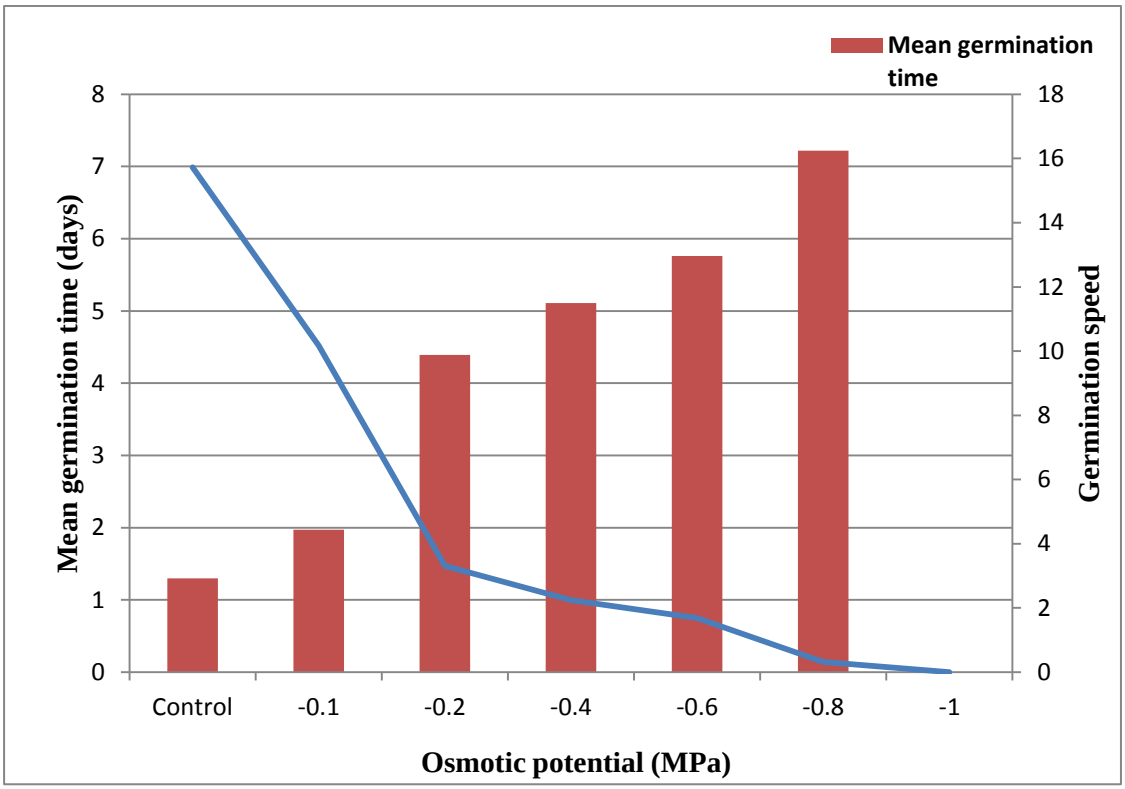

Figure 4.14: Effect of moisture stress on mean germination time and germination speed of *Portulaca oleracea* L.

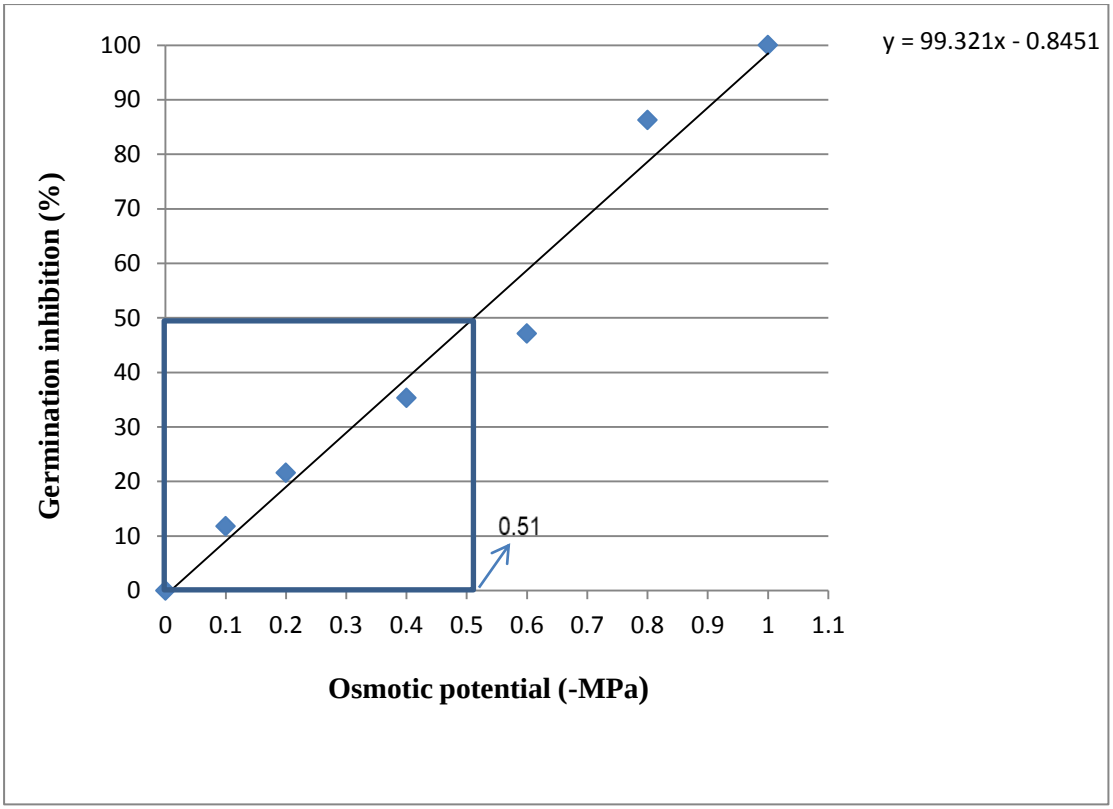

Figure 4.15: Osmotic potential required for 50% inhibition of germination in *Portulaca oleracea* L.

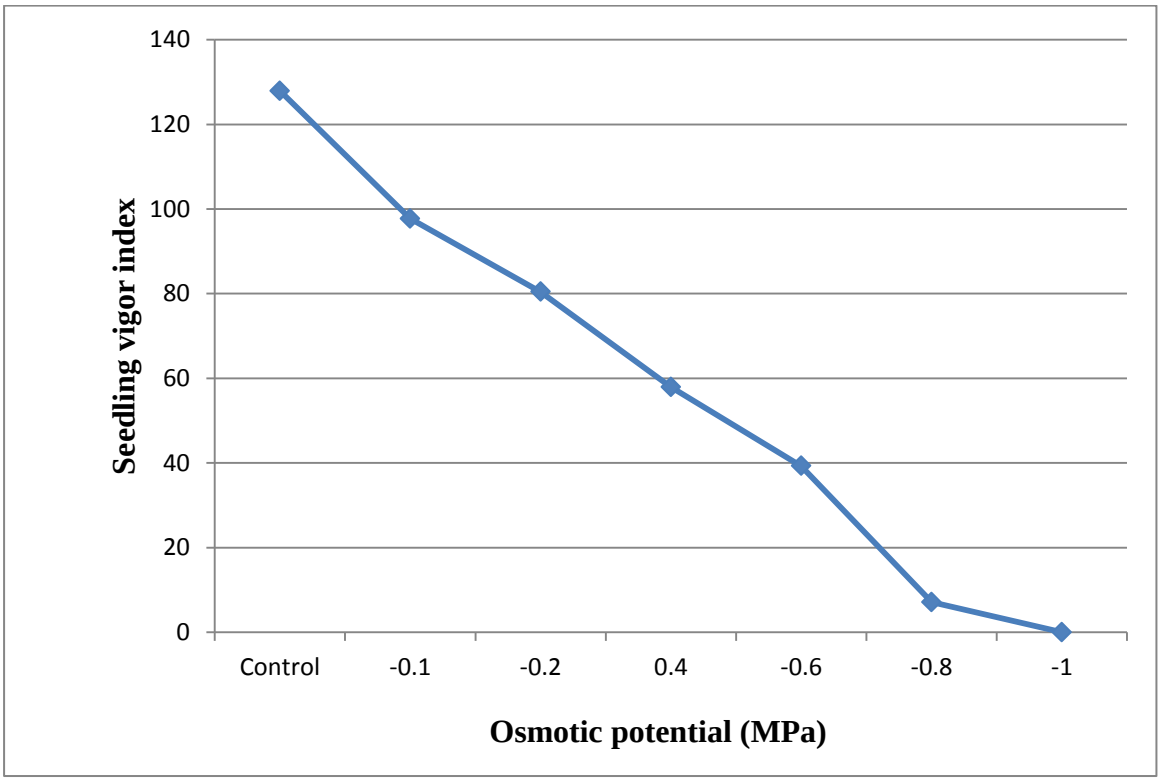

Figure 4.16: Effect of moisture stress on seedling vigor index of *Portulaca oleracea* L.

4.7: Effect of seed burial depth on germination of *Portulaca oleracea* L.

Burial depth of seeds significantly affected germination and seedling emergence of *Portulaca oleracea*. There was 43.3 per cent points decrease in germination with increase in seed burial depth from 0 to 2 cm. Germination was completely inhibited at depths greater than 2 cm (Plate 4.2). There was increase in mean germination time with concomitant decrease in speed of germination when burial depth was increased from 0 to 2 cm (Table 4.13 and Figs. 4.17-4.18). Time to start germination increased by 2 days at depth of 2 cm as compared to its control.

Burial of the seeds in deeper soil layers is considered beneficial for seed persistence as air exposure is reduced, high humidity levels are maintained and seeds are protected against high temperature, granivores and herbivores (Forcella *et al* 2000). However, soil depth has also inhibitory effects as it prevents penetration of light and reduces soil gas diffusion; thereby preventing seed germination (Benvenuti 2003). Seed size and shape also influence germination when seeds are sown at deeper layers of soil. Large-seeded species have ability to emerge from greater depths as they have greater storage reserves as compared to small-seeded species to support the emergence of seedlings from deeper soil layers. The experiment conducted by Chauhan and Johnson (2009) reported that germination of *P. oleracea* population from Philippines sharply decreased from 63 to 1% with increase in burial depth from 0 to 1 cm. In present study, North-Indian population of *P. oleracea* exhibited maximum germination at burial depth of 0 and 0.5 cm. Germination of *P.oleracea,* population from North-India was completely inhibited at 3 cm; whereas germination of *P. oleracea*, population from Philippines was completely inhibited at burial depth of 2 cm. Inhibition of seedling emergence in *P. oleracea* from greater soil depth is possibly due to small seed size (1000 seed weight=1.40 g) and due to presence of limited storage reserves. Maximum number of seedlings (82%) of *Eleusine indica* emerged from the soil surface; thereafter emergence decreased from 63 to 4% with increase in burial depth from 0.5 to 6 cm and germination was completely inhibited at 8 cm (Chauhan and Johnson 2008a). Chauhan and Johnson (2008c) recorded that 98 and 94% germination of *Digitaria ciliaris* and *Digitaria longiflora* occurred on the soil surface. Germination of *Digitaria ciliaris* reduced from 98 to 5% with increase in burial depth from 0 to 6 cm; whereas germination of *Digitaria longiflora* decreased from 94 to 1% with increase in burial depth from 0 to 1 cm. Seedling emergence of *D. longiflora* and *D. ciliaris* was completely inhibited at 2 and 8 cm, respectively. When seeds of *D. ciliaris* were brought from 8 cm depth to soil surface, more than 90% seed germination was recorded. This indicates that cropped-areas can be prevented from

re-infestation with small-seeded species like *P. oleracea* by shallow tillage operations which prevent bringing seeds from deeper soil layers back to soil surface.

Table 4.13: Effect of seed burial depth on germination of *Portulaca oleracea* L.

Seed burial depth (cm)	Germination (%)	Time to start germination (days)	Germination speed	Mean germination time (days)
0	58.33±2.89	14.00±0	0.74±0.24	15.56±0.70
0.5	58.33±2.89	14.00±0	0.73±0.14	15.57±0.40
1	30.00±5.00	14.00±0	0.39±0.06	16.50±0.87
2	15.00±5.00	16.00±1.00	0.19±0.08	17.04±0.82
3	NG	NG	NG	NG
4	NG	NG	NG	NG
5	NG	NG	NG	NG
LSD (p=0.05)	5.55	0.67	0.22	0.97

Data are mean±standard deviation

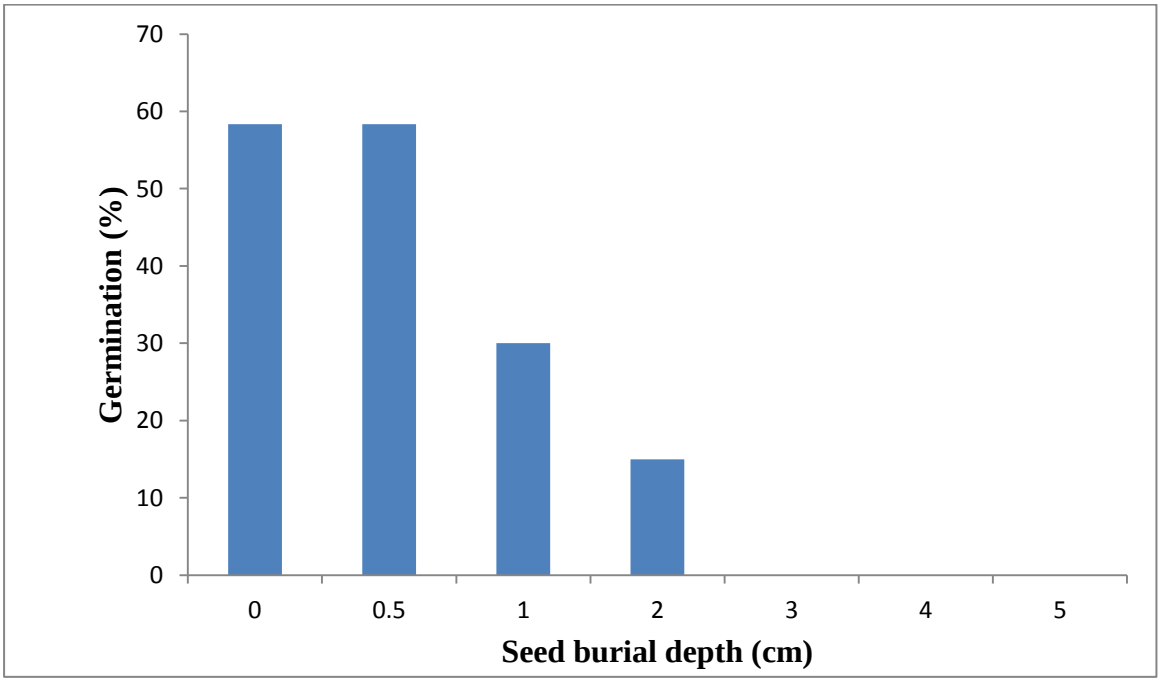

Figure 4.17: Effect of seed burial depth on germination of *Portulaca oleracea* L.

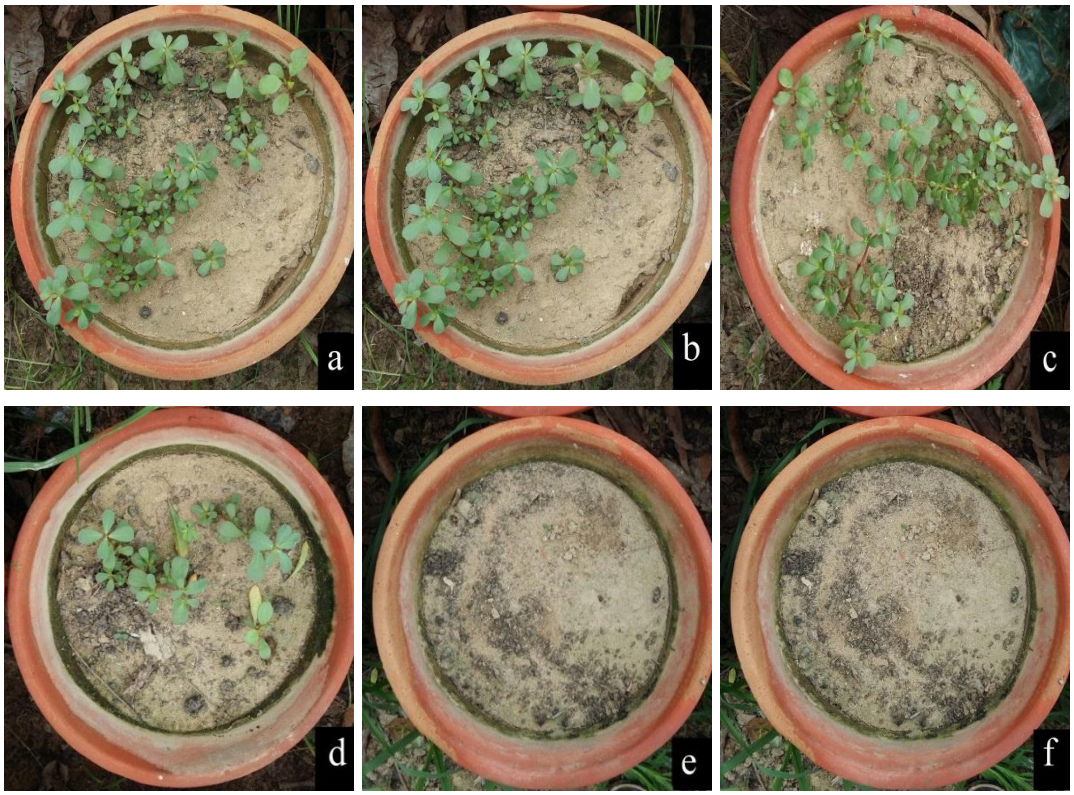

Plate 2: Seeds of *Portulaca oleracea* sown at different burial depths. Seeds sown at a depth of a) 0 cm, b) 0.5 cm, c) 1 cm, d) 2 cm, e) 3 cm, f) 4 cm.

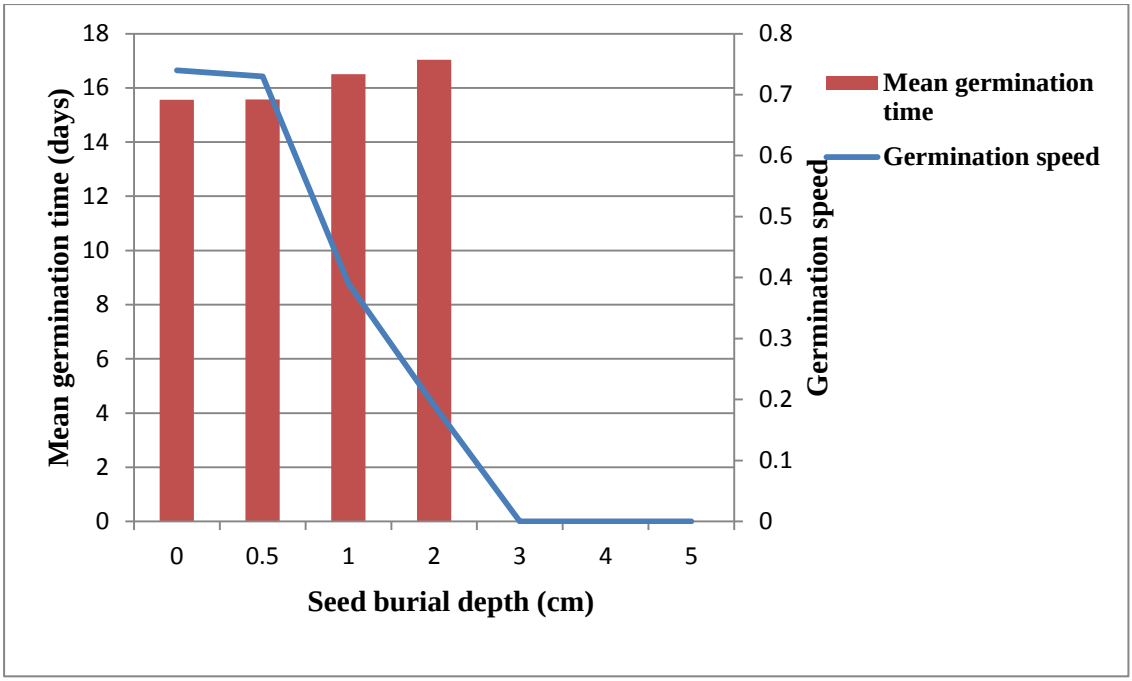

Figure 4.18: Effect of seed burial depth on mean germination time and germination speed of *Portulaca oleracea* L.

4.8 Effect of pre-emergence herbicides on emergence of *Portulaca oleracea* L.

The effect of five pre-emergence herbicides viz., pendimethalin (750, 563 and 375 g/ha), clomazone (400, 300 and 200 g/ha), oxadiargyl (90, 68 and 45 g/ha), oxyfluorfen (240, 180 and 120 g/ha) and sulfentrazone (360, 270 and 180 g/ha), was studied against the emergence of this weed. All the herbicides were very effective in controlling emergence of *P. oleracea*. Emergence of *P. oleracea* seeds was found to be sensitive to all the tested herbicides. Maximum emergence was observed in control. Three herbicides viz., pendimethalin, oxyfluorfen and sulfentrazone at all the dose rates exhibited complete control of *P. oleracea* and no emergence was observed in these treatments. Clomazone at all the dose rates and oxadiargyl at its lowest dose application i.e. 45 g/ha allowed some emergence of *P. oleracea*, but at higher dose rates oxadiargyl also exhibited complete inhibition of emergence of *P. oleracea* (Table 4.14).

Pre-emergence herbicides are effective in preventing germination of weed seeds and various herbicides differ in their mode of action. Oxyfluorfen, sulfentrazone and oxadiargyl belongs to diphenylether, aryl triazolinone and oxadiazoles family, respectively and these herbicides are the inhibitors of protoporphyrinogen oxidase. Clomazone belongs to isoxazolidinone family and is pigment-synthesis inhibitor. Pendimethalin, a member of dinitroaniline family is a root growth inhibitor (Sherwani *et al* 2015). Pendimethalin (0.43 and 0.86 kg/ha) has been reported to be more than 80% effective in controlling emergence of *P. oleracea* in leafy green vegetables like turnip (*Brassica rapa*), mustard (*Brassica*

rapa), cabbage (*Brassica oleracea*) and kale (*Brassica oleracea*) (Norsworthy and Smith 2005). Brown and Masiunas (2002) recorded more than 80 and 70% control of *P. oleracea* with clomazone (0.28 and 0.37 kg/ha) and sulfentrazone (0.28 kg/ha), respectively in pumpkin (*Cucurbita pepo*). Prithvi *et al* (2015) recorded significantly low weed density of weeds like *Cynodon dactylon, Digitaria marginata, Trianthema portulacastrum, Sesanum ekamberi* and *Portulaca oleracea* when oxadiargyl (100 g/ha) was applied as pre-emergence herbicide. When oxyfluorfen (0.25 kg a.i. /ha) was applied as pre-emergence herbicide, density of weeds like *Ageratum conyzoides, Gnaphalium peregrinum, Plantago lanceolata,Cynodon dactylon, Amaranthus viridis, Paspalum dilatatum, Portulaca oleracea, Euphorbia hiria, Oxalis corniculata, Trifolium repens, Imperata cylindrica* and *Digitaria adscendance* was 110 plants per m² as compared to 491 plants per m² in control (Manju *et al* 2005). In present study, oxyfluorfen (240, 180 and 120 g/ha), pendimethalin (750, 563 and 375 g/ha), sulfentrazone (360, 270 and 180 g/ha) were 100% effective in suppressing North-Indian population of *P. oleracea*. Even oxadiargyl and clomazone recorded either more than 90% or complete control of *P. oleracea*.

Table 4.14: Effect of pre-emergence herbicides on emergence of *Portulaca oleracea* L.

Herbicides	Mode of action	Site of action	Doses (g/ha)	Weed density (No. Pot^{-1})
Control			-	11.67±0.58
Oxadiargyl	Cell membrane disrupter	Protoporphyrinogen oxidase inhibitor	45	0.67±0.58
			68	0
			90	0
Clomazone	Pigment-synthesis inhibitor	Diterpene-synthesis inhibitor	200	1.00±1.00
			300	1.67±0.58
			400	1.00±1.00
Oxyfluorfen	Cell membrane disrupters	Protoporphyrinogen oxidase inhibitor	120	0
			180	0
			240	0
Pendimethalin	Root growth inhibitor	Microtubule inhibitor	375	0
			563	0
			750	0
Sulfentrazone	Cell membrane disrupters	Protoporphyrinogen oxidase inhibitor	180	0
			270	0
			360	0
LSD (p=0.05)				0.64

Data are mean±standard deviation

In conclusion, different environmental factors like temperature, salinity, pH, osmotic stress and seed burial depth had significant effect on germination of *Portulaca oleracea*. Seed priming with distilled water and different concentrations of gibberellic acid proved to be effective in breaking seed dormancy of this weed. Seed germination was increased to 81% when seeds were pre-soaked in 1000 ppm gibberellic acid for 24 hrs as compared to 27% germination in control. Optimum temperature required for germination of *P. oleracea* was 30°C. However, seeds were able to germinate over a wide temperature range from 20 to 32°C. Light was not necessary for germination of this weed as germination was observed in both light and dark at all the tested temperatures. *P. oleracea* had ability to withstand high salinity as some germination (17%) was observed even in presence of 250 mM NaCl. However, seedlings grown under salinity stress showed reduced growth as compared to control. NaCl concentration that caused 50% inhibition of germination was 163.56 mM. Germination of *P. oleracea* was observed in all the tested pH range i.e. 6.5 to 8.5. Maximum germination was observed in control (pH 7); and either increase or decrease in pH reduced germination of this weed. The seeds of *P. oleracea* were very sensitive to moisture stress as germination decreased with decrease in osmotic potential and germination was completely suppressed at -1.0 MPa. Germination was reduced to 12% at -0.8 MPa osmotic potential as compared to 85% germination in control. Germination decreased with increase in soil depth and complete inhibition of germination occurred at soil depth greater than 2 cm. Inhibition of seedling emergence in *P. oleracea* from greater soil depths is possibly due to small seed size and limited storage reserves as germination of this weed can occur in the absence of light. Emergence of *P. oleracea* seeds was found to be sensitive to all the tested herbicides viz., oxyfluorfen (240, 180 and 120 g/ha), pendimethalin (750, 563 and 375 g/ha), sulfentrazone (360, 270 and 180 g/ha), oxadiargyl (90, 68 and 45 g/ha) and clomazone (400, 300 and 200 g/ha). Clomazone at all the dose rates and oxadiargyl at its lowest dose application i.e. 45 g/ha allowed some emergence of *P. oleracea* (more than 90% reduction in emergence as compared to control), but at higher dose rates oxadiargyl also exhibited complete inhibition of emergence of *P. oleracea*. Other three herbicides viz., pendimethalin, oxyfluorfen and sulfentrazone caused complete germination inhibition at all the applied dose rates.

CHAPTER-V

SUMMARY

The present study was conducted to investigate the effect of environmental variables on germination ecology of *Portulaca oleracea* L. Effect of seed priming with gibberellic acid (200, 500 and 1000 ppm) was studied to overcome the seed dormancy in *P. oleracea*. Effect of different environmental factors viz., temperature (20, 22, 24, 26, 28, 30 and 32°C), light (24 hrs light and 24 hrs dark), salinity (25, 50, 75, 100, 150, 200, 250 and 300 mM), pH (6, 6.5, 7, 7.5, 8 and 8.5), osmotic stress (0, -0.1, -0.2, -0.4, -0.6, -0.8 and -1.0 MPa) and seed burial depth (0, 0.5, 1, 2, 3, 4 and 5 cm) was studied on germination and early seedling growth of *P. oleracea*. Effect of pre-emergence herbicides viz., oxyfluorfen (240, 180 and 120 g/ha), pendimethalin (750, 563 and 375 g/ha), sulfentrazone (360, 270 and 180 g/ha), oxadiargyl (90, 68 and 45 g/ha) and clomazone (400, 300 and 200 g/ha) was also studied on seedling emergence of *P. oleracea*.

A) Seed priming with gibberellic acid

- Germination of *P. oleracea* was significantly increased due to gibberellic acid treatment.
- Soaking of seeds in 1000 ppm GA for 24 hrs was found to be most effective in overcoming seed dormancy. Seed germination was increased to 81% as compared to 27% in control.

B) Temperature

- Optimum temperature required for germination of *P. oleracea* was 30°C. But seeds were able to germinate in wide temperature range of 20-32°C.
- There was increase in germination with rise in temperature from 20 to 30°C and seed germination decreased with further increase in temperature to 32°C.
- There was decrease in mean germination time and time to start germination with concomitant increase in germination speed as the temperature was increased from 20 to 30°C.

C) Light

Seeds of *P. oleracea* were able to germinate in both light and dark regimes at all the tested temperatures. This indicates that the light is not essential for germination of *P. oleracea.*

D) Salinity

- Seeds of *P. oleracea* were able to germinate under wide range of NaCl concentration (25-250 mm) indicating the ability of this weed to tolerate salinity. However, there was decrease in germination with increase in

concentration of NaCl from 0 to 250 mM.

- The germination of *P. oleracea* was completely suppressed at 300 mM NaCl; while concentration causing 50% reduction in germination of *P. oleracea* seeds was 163.56 mM NaCl.
- *P. oleracea* seedlings grown under salinity stress showed reduced growth as compared to control.
- Germination speed and seedling vigor index reduced with concomitant increase in mean germination time and time to start germination with the rise in NaCl concentration.

E) pH

- *P. oleracea* was able to germinate in all the tested pH range (6.5-8.5).
- Maximum germination of *P. oleracea* was observed in control (pH=7); and either decrease or increase in pH from pH 7 resulted in reduction of germination.
- Seedling vigor index was observed to be maximum in control and a decrease was observed at pH <7 or >7.

F) Moisture stress

- Moisture stress increased the time to start germination and mean germination time with concomitant decrease in germination speed.
- There was decrease in germination with decrease in osmotic potential from 0 to -0.8 MPa and seed germination was completely inhibited at -1.0 MPa.
- 50% germination was inhibited at -0.51 MPa osmotic potential.

G) Seed burial depth

- Seeds sown on the soil surface recorded maximum germination.
- There was decrease in germination with increase in soil depth and complete inhibition of germination was observed at soil depth of 3cm and greater than 3 cm.
- Inhibition of seedling emergence in *P. oleracea* from greater soil depths is probably due to small seed size and inadequate storage reserves as germination of this weed can occur in the absence of light.

H) Pre-emergence herbicides

- All the tested pre-emergence herbicides were effective in controlling emergence of *P. oleracea*.
- Emergence of *P. oleracea* seeds was found to be sensitive to all the tested herbicides viz., oxyfluorfen (240, 180 and 120 g/ha), pendimethalin (750, 563 and 375 g/ha), sulfentrazone (360, 270 and 180 g/ha), oxadiargyl (90, 68 and

45 g/ha) and clomazone (400, 300 and 200 g/ha).

- Three herbicides viz., pendimethalin, oxyfluorfen and sulfentrazone at all the dose rates exhibited complete control of *P. oleracea* and no emergence was observed in these treatments.
- Clomazone at all the dose rates and oxadiargyl at its lowest dose application i.e. 45 g/ha allowed some emergence of *P. oleracea* (more than 90% reduction in emergence as compared to control), but at higher dose rates oxadiargyl also exhibited complete inhibition of emergence of *P. oleracea*.

REFERENCES

Abdul Baki A A and Anderson J D (1973) Vigour determinations in soybean seed multiple criteria. *Crop Sci* **13**: 630-33.

Abdullatif Z, Sebayang H T, Sudiarso and Nugroho A (2016) Effect of cutting and watering of *Portulaca oleracea* L. on weeds control. *Int J Plant Res* **6**:1-6.

Allegra M, Reiter R J, Tan D X, Gentile C, Tesoiere L and Livrea M A (2003) The chemistry of melatonin's interaction with reactive species. *J Pineal Res* **34**:1-10.

Amini R and Abdi H (2014) Germination and early seedling growth of common purslane (*Portulaca oleracea* L.) affected by salinity and osmotic stress. *Int J Biosci* **5**: 342-49.

Amini R, Alizadeh H and Yousefi A (2014) Interference between red kidneybean (*Phaseolus vulgaris* L.) cultivars and redroot pigweed (*Amaranthus retroflexus* L.). *Eur J Agron* **60**: 13-21.

Amini R, An M, Prately J and Azimi S (2009) Allelopathic assessment of annual ryegrass (*Lolium rigidum*) : Bioassay. *Allelopathy J* **24**: 67-76.

Anonymous (2008) Agricultural Statistics of Pakistan. Ministry of food, agriculture and livestock (Economic wing), Government of Pakistan (Islamabad).

Aringhieri R (2010) The salt problem in soil: an overview. *Environ Qual* **5**: 15-22.

Asgarpour R, Ghorbani R, Khajeh-Hosseini M, Mohammadvand E and Chauhan B S (2015) Germination of spotted spurge (*Chamaesyce maculata*) seeds in response to different environmental factors. *Weed Sci* **63**: 502-10.

Association of Official Seed Analysts (1983) Rules for testing seeds. *J Seed Technol* **16**: 1-113.

Awan T H, Chauhan B S and Cruz P C S (2014) Influence of environmental factors on the germination of *Urena lobata* L. and its response to herbicides. *PLoS One* **9**: 1-8.

Balouchi S and Sanavy S A M M (2006) Effect of gibberellic acid, prechilling, sulphuric acid and potassium nitrate on seed germination and dormancy of annual medics. *Pak J Biol Sci* **9(15)**: 2875-80.

Barcelo J, Poschenrieder C, Vazquez M D and Gunse B (1996) Aluminium phytotoxicity :A challenge for plant scientists. *Fert Res* **43**: 217-23.

Baziramakenga R, Leroux G D and Simard R R (1995) Effects of benzoic and cinnamic acids on membrane permeability of soybean roots. *J Chem Ecol* **21**: 1271-85.

Behravan J, Mosafa F, Soudmand N, Taghiabad E, Razavi B M and Karimi G (2011) Protective effects of aqueous and ethanolic extracts of *Portulaca oleracea* L. aerial parts on H_2O_2- induced DNA damage in lymphocytes by comet assay. *J Acupunct Meridian Stud* **4**: 193-97.

Benvenuti S (2003) Soil texture involvement in germination and emergence of buried weed seeds. *Agron J* **95**: 191-98.

Benvenuti S, Dinelli G and Bonetti A (2004) Germination ecology of *Leptochloa chinensis*: a new weed in the Italian rice agro-environment. *Weed Res* **44**: 87-96.

Benvenuti S, Macchia M and Miele S (2001) Quantitative analysis of emergence of seedlings from buried weed seeds with increasing soil depth. *Weed Sci* **49**: 528-35.

Berkat O and Briske D D (1982) Water potential evaluation of three germination substrates utilizing polyethylene glycol 20,000. *Agron J* **74**: 518-21.

Bewley J D (1997) Seed germination and dormancy. *Plant Cell* **9**: 1055-66.

Bewley J D and Black M (1994) Seeds germination, structure and composition. In: Bewley J D and Black M (ed) *Seeds-physiology of development and germination.* Pp 1-33. Plenum Press, New York.

Bhardwaj A K, Kapoor S, Naryal A, Bhardwaj P, Warghat A R, Kumar B and Chauraisa O P (2016) Effect of various dormancy breaking treatments on seed germination, seedling growth and seed vigour of medicinal plants. *Trop Plant Res* **3**: 508-16.

Blackshaw R E (1990) Influence of soil temperature, soil moisture, and seed burial depth on the emergence of round-leaved mallow (*Malva pusilla*). *Weed Sci* **38**: 518-21.

Bolfrey-Arku G E K, Chauhan B S and Johnson D E (2011) Seed germination ecology of itchgrass (*Rottboellia cochinchinensis*). *Weed Sci* **59**: 182-87.

Brown D and Masiunas J (2002) Evaluation of herbicides for pumpkin (*Cucurbita* spp.). *Weed Technol* **16**: 282-92.

Burke I C, Thomas W E, Spears J F and Wilcut J H (2003) Influence of environmental factors on after-ripened crowfootgrass (*Dactyloctenium aegyptium*) seed germination. *Weed Sci* **51**: 342-47.

Cavero J, Aibar J, Gutierrez M, Fernandez-Cavada S, Sopena J M, Pardo A, Suso M L and Zaragoza C (2001) Tolerance of direct-seeded paprika pepper (*Capsicum annuum*) to clomazone applied preemergence. *Weed Technol* **15**: 30-35.

Cavero J, Zaragoza C and Gil-Ortega R (1996) Tolerance of direct-seeded pepper (*Capsicum annuum*) under plastic mulch to herbicides. *Weed Technol* **10**: 900-06.

Chachalis D and Reddy N K (2000) Factors affecting *Campsis radicans* seed germination and seedling emergence. *Weed Sci* **48**: 212-16.

Chan K, Islam M W, Kamil M, Radhakrishnan R, Zakaria M N M, Habibullah M and Attas A (2000) The analgesic and anti-inflammatory effects of *Portulaca oleracea* L. subsp. *sativa* (Haw.) Celak. *J Ethnopharmacology* **73**: 445-51.

Chapman J, Stewart R B and Yarnell R A (1974) Archaeological evidence for pre-columbian introduction of *Portulaca oleracea* and *Mollugo verticillata* into eastern North America. *Econ Bot* **28**: 411-12.

Chauhan B S (2011) Crowfootgrass (*Dactyloctenium aegyptium*) germination and response to herbicides in the Philippines. *Weed Sci* **59**: 512-16.

Chauhan B S and Johnson D E (2008a) Germination ecology of goosegrass (*Eleusine indica*) : an important grass weed of rainfed rice. *Weed Sci* **56**: 699-706.

Chauhan B S and Johnson D E (2008b) Influence of environmental factors on seed germination and seedling emergence of Eclipta (*Eclipta prostrata*) in a tropical environment. *Weed Sci* **56**:383-88.

Chauhan B S and Johnson D E (2008c) Germination ecology of southern crabgrass (*Digitaria ciliaris*) and India crabgrass (*Digitaria longiflora*): two important weeds of rice in tropics. *Weed Sci* **56**: 722-28.

Chauhan B S and Johnson D E (2009) Seed germination ecology of *Portulaca oleracea* L.: an important weed of rice and upland crop. *Ann Appl Biol* **155**: 61-69.

Chauhan B S, Gill G and Preston C (2006a) Seedling recruitment pattern and depth of recruitment of 10 weed species in minimum tillage and no-till seeding systems. *Weed Sci* **54**: 891-97.

Chauhan B S, Gill G and Preston C (2006b) Factors affecting seed germination of little mallow (*Malva parviflora*) in southern Australia. *Weed Sci* **54**: 1045-50.

Chen C J, Wang W Y, Wang X L, Dong LW, Yue Y T, Xin H J, Ling C Q and Li M (2009) Anti-hypoxic activity of the ethanol extract from *Portulaca oleracea* in mice. *J Ethnopharmacol* **124**: 246-50.

Cirak C, Ayan A K and Kevseroglu K (2004) The effects of light and some presoaking treatments on germination rate of St. John's Worth seeds. *Pak J Biol Sci* **7**: 182-86.

Cochran W G and Cox G M (1966) *Experimental Designs*. Pp. 545-68 John Wiley, New York.

Cuzzocrea S, Tan D X, Costantino G, Mazzon E, Caputi A P and Reiter R J (1999) The protective role of endogenous melatonin in carrageenan-induced pleurisy in the rat. *Faseb J* **13**: 1930-38.

Debeaujon I and Koornneef M (2000) Gibberellin requirement for *Arabidopsis* seed germination is determined both by testa characteristics and embryonic abscisic acid. *Plant Physiol* **122**: 415-24.

Deli J and Warren G F (1970) Uptake, translocation and herbicidal effect of diphenamid. *Weed Sci* **18**: 692-96.

Dusky J A and Stall W M (1996) Evaluation of imazethapyr for weed control in leafy vegetable crops. *Weed Technol* **10**: 253-57.

Egley G H (1974) Dormancy variations in common purslane seeds. *Weed Sci* **22**: 535-40.

Egley G H and Duke S O (1985) Physiology of weed seed dormancy and germination. In: Duke S O (ed) *Weed Physiology: Reproduction and Ecopyhsiology*. Pp 27-64. CRC Press, Boca Raton.

Ellis R A and Roberts E H (1981) The quantification of ageing and survival in orthodox seeds. *Seed Sci Technol* **9**: 373-409.

Evetts L L and Burnside O C (1972) Germination and seedling development of common milkweed and other species. *Weed Sci* **20**:371-78.

Fennimore S A, Smith R F and McGiffen M E (2001) Weed management in fresh market spinach (*Spinacia oleracea*) with S-metolachlor. *Weed Technol* **15**: 511-16.

Forcella F, Arnold R L B, Sanchez R and Ghersa C M (2000) Modeling seedling emergence. *Field Crops Res* **67**: 123-39.

Foy CD (1984) Physiological effects of hydrogen, aluminium and manganese toxicities in acid soil. In: Adams F (ed) *Soil acidity and liming*. Pp. 57-97 Library of Congress Cataloging in Publication Data, Wisconsin, USA.

Ganepour S, Amini R and Mobli A (2004) Initial seedling growth of pepperweed (*Lepidium perfoliatum* L.) as affected by salinity and burial depth. *Int J Agril Innov Res* **2(5)**: 846-49.

Gentili R, Ambrosini R, Montagnani C, Caronni S and Citterio S (2018) Effect of soil pH on the growth, reproductive investment and pollen allergenicity of *Ambrosia artemisiifolia* L. *Front Plant Sci* **9**: 1-12.

Ghosheh H Z (2004) Single herbicide treatments for control of broadleaved weeds in onion (*Allium cepa*). *Crop Prot* **23**: 539-42.

Gorske S F and Hopen H J (1978) Selectivity of nitrofen and oxyfluorfen between *Portulaca oleracea* ecotypes and two cabbage (*Brassica oleracea* var. capitata) cultivars. *Weed Sci* **26**: 640-42.

Greenway H and Munns R (1980) Mechanisms of salt tolerance in non-halophytes. *Ann Rev Plant Physiol* **31**: 149-90.

Haar M J and Fennimore S A (2003) Evaluation of integrated practices for common purslane (*Portulaca oleracea*) management in lettuce (*Lactuca sativa*). *Weed Technol* **17**: 229-33.

Hohl M and Peter S (1991) Water relations of growing maize coleoptiles. Comparison between mannitol and polyethylene glycol 6000 as external osmotica for adjusting turgor pressure. *Plant Physiol* **95**: 716-22.

Hoyt G D, Bonanno A R and Parker G C (1996) Influence of herbicides and tillage on weed control, yield and quality of cabbage (*Brassica oleracea* L. var. *capitata*). *Weed Technol* **10**: 50-54.

Jacobs J M and Jacobs N J (1987) Oxidation of protoporphyrinogen to protoporphyrin, a step in chlorophyll and heme biosynthesis. *Biochem J* **244**: 219-24.

Karlsson L M, Tamado T and Milberg P (2008) Inter-species comparison of seed dormancy and germination of six annual asteraceae weeds in an ecological context. *Seed Sci* **18**: 35-45.

Karssen C M, Brinkhorst-vander S D L C, Breekland A E and Koornneef M (1983) Induction of dormancy during seed development by endogenous abscisic acid: studies on abscisic acid deficient genotypes of *Arabidopsis thaliana* (L.) Heynh. *Planta* **157**: 158-65.

Koch K and Kennedy R A (1980) Characteristics of crassulacean acid metabolism in the succulent C_4 dicot (*Portulaca oleracea* L.). *Plant Physiol* **65**: 193-97.

Koger C H, Reddy K N and Poston D H (2004) Factors affecting seed germination, seedling emergence, and survival of texasweed (*Caperonia palustris*). *Weed Sci* **52:** 989–95.

Kolar J and Machackova I (2005) Melatonin in higher plants: occurrence and possible functions. *J Pineal Res* **39**: 333-41.

Kovacevic J and Bukovac P (1974) The weed flora of tobacco fields in the Drava river valley. *Agron Glasnik* **36**: 419-26.

Kruk B C and Benech- Arnold R L (2000) Evaluation of dormancy and germination responses to temperature in *Carduus acanthoides and Anagallis arvensis* using a screening system, and relationship with field-observed emergence patterns. *Seed Sci Res* **10**: 77-88.

Li H S, Sun Q, Zhao S J and Zhang W H (2000) *Principles and Techniques of Plant Physiol Biochem Exp* Pp. 267-71. Higher Education Press, Beijing.

Lim Y Y and Quah E P L (2007) Antioxidant properties of different cultivars of *Portulaca oleracea*. *Food Chem* **103(3)**: 734-40.

Lu P, Sang W and Ma K (2006) Effects of environmental factors on germination and emergence of Crofton weed (*Eupatorium adenophorum*). *Weed Sci* **54(3)**: 452-57.

Macchia M, Angelini L G and Ceccarini L (2001) Methods to overcome seed dormancy in *Echinacea angustifolia* DC. *Sci Hort* **89**: 317-24.

Makowski R M D and Morrison I N (1989) The biology of Canadian weeds, 91: *Malva pusilla* Sm. (*M. rotundifolia* L.). *Can J Plant Sci* **69**: 861-79.

Malek F, Boskabady M H, Borushaki M T and Tohidi M (2004) Bronchodilatory effect of *Portulaca oleracea* in airways of asthmatic patients *J Ethnopharmacology* **93**: 57-62.

Manju S, Ram R, Singh R D and Mukherjee D (2005) Evaluation of different herbicides for protection of gladiolus (*Gladiolus* spp.) crop from weeds.

Crop Prot **24**: 921-26.

Michel B E and Kaufmann M R (1973) The osmotic potential of polyethylene glycol 6000. *Plant Physiol* **51**: 914-16.

Mitich L W (1997) Common purslane (*Portulaca oleracea*). *Weed Technol* **11**: 394-97.

Miyanishi K and Cavers P B (1980) The biology of Canadian weeds. 40. *Portulaca oleracea* L. *Can J Plant Sci* **60**: 953-63.

Munns R and Tester M (2008) Mechanisms of salinity tolerance. *Annu Rev Plant Biol* **59**: 651-81.

Niu G and Dan Z (2005) Progress on chemical compositions and pharmacological function of *Portulace oleracea* L. *J Anhui Agric Sci* **33**: 1090-92.

Norsworthy J K and Smith J P (2005) Tolerance of leafy greens to preemergence and postemergence herbicides. *Weed Technol* **19**: 724-30.

Nyffeler R and Eggli U (2010) Disintegrating Portulacaceae: a new familial classification of the suborder Portulacineae (Caryophyllales) based on molecular and morphological data. *IAPT* **59**: 227-40.

Patane C, Saita A and Sortino O (2013) Comparative effects of salt and water stress on seed germination and early embryo growth in two cultivars of sweet sorghum. *J Agron Crop Sci* **199**: 30-37.

Prithvi B K, Rao A S and Srinivasulu K (2015) Weed management in transplanted ragi. *Indian J Weed Sci.* **47**: 214-15.

Proctor C A (2013) *Biology and control of common purslane* (*Portulaca oleracea* L.). Ph.D. dissertation. University of Nebraska, Lincoln.

Proctor C A and Reicher Z J (2013) Efficacy of preemergence and postemergence herbicides for controlling common purslane. *Hort Sci* **48**: 902-5.

Qureshi R H and Barrett-lennard E G (1998) *Saline agriculture for irrigated land in Pakistan: a handbook.* Pp. 5-17 Australian Centre for International Agricultural Research Canberra, Australia.

Reddy K N and Singh M (1992) Germination and emergence of hairy beggarticks (*Bidens pilosa*). *Weed Sci* **40**: 195-99.

Rezvani M and Yazdi S A (2013) Factors affecting seed germination of black nightshade (*Solanum nigrum*). *Acta Botanica Hungarica* **55**: 397-408.

Shakya S K and Singh J P (2010) New drainage technologies for salt-affected waterlogged areas of southwest Punjab, India. *Curr Sci* **99**:204-12.

Shaw D R, Mack R E and Smith C A (1991) Redvine (*Brunnichia ovata*) germination and emergence. *Weed Sci* **39**: 33-36.

Sherwani S I, Arif I A and Khan H A (2015) Modes of action of different classes of herbicides. In: Price A, Kelton J and Sarunaite L (ed) *Herbicides, Physiology of Action and Safety.* Pp 165-86. Intech open, USA.

Sidari M, Santonoceto C, Anastasi U, Preiti G and Muscolo A (2008) Variations in four genotypes of lentil under NaCl-salinity stress. *Am J Agric Biol Sci* **3**: 410-16.

Simopoulos A P, Norman H A, Gillaspy J E and Duke J A (1992) Common purslane: a source of omega-3 fatty acids and antioxidants. *J Am Coll Nutr* **11**: 374-82.

Simopoulos A P, Tan D X, Manchester L C and Reiter R J (2005) Purslane: a plant source of omega-3 fatty acids and melatonin. *J Pineal Res* **39**: 331-32.

Singh S and Benbi D (2016) Punjab- soil health and green revolution: A quantitative analysis of major soil parameters. *J Crop Improv* **30**: 323-40.

Singh S and Singh M (2009) Effect of temperature, light and pH on germination of twelve weed species. *Weed Sci* **41**: 113-26.

Souza G M and Cardoso V J M (2000) Effects of different environmental stresses on seed germination. *Seed Sci Technol* **28**: 621-30.

Tanveer A, Mumtaz K, Javaid M M, Chaudhry M N, Balal R M and Khaliq A (2013) Effect of ecological factors on germination of horse purslane (*Trianthema portulacastrum*). *Planta Daninha* **31(3)**: 587-97.

Tanveer A, Tabassum F, Abbas R N, Tahir M, Javaid M M, Aziz A and Siddiqui M H (2012) Seed germination ecology of *Lathyrus aphaca* L. and *Vicia sativa* L. in comparison with *Triticum aestivum* L. *Pak J Weed Sci Res* **18(3)**: 293-305.

Theodoridis G, Baum J S, Holtzman F W, Manfredi M C, Maravetz L L, Lyga J W, Tymonko J M, Wilson K R, Poss K M and Wyle M J (1992). Synthesis and herbicidal properties of aryltriazolinones: A new class of pre- and postemergence herbicides. In: Baker D R, Fenyes J G and Steffens J J (ed) *Synthesis and Chemistry of Agrochemicals III*. Pp 135-46. American Chemical Society, Washington, DC.

Tiwari K K , Dwivedi S, Mishra S, Srivastava S , Tripathi R D, Singh N K and Chakraborty S (2008) Phytoremediation efficiency of *Portulaca tuberosa* rox and *Portulaca oleracea* L. naturally growing in an industrial effluent irrigated area in Vadodra, Gujrat, India. *Environ Monit Assess* **147**: 15–22.

Uddin Md K, Juraimi A S, Hossain Md S, Unnahar M A, Ali Md E and Rahman M M (2014) Purslane weed (*Portulaca oleracea*): A prospective plant source of nutrition, omega-3 fatty acid and antioxidant attributes. *Sci World J* **2014**: 1-6.

Walters M and Figueiredo E (2011) Portulacaceae. In: Waltera M, Figueiredo E, Crouch N R, Winter P J D, Smith G F,Zimmermann H G and Mashope B K (ed) *Naturalised and invasive succulents of Southern Africa*. Pp 293-99. ABC Taxa, South Africa.

Wang W, Gu L, Dong L, Wang X, Ling C and Li M (2007) Protective effect of *Portulaca oleracea* extracts on hypoxic nerve tissue and its mechanism. *Asia Pac J Clin Nutr* **16**: 227-33.

Wanyin W, Liwei D, Lin J, Hailiang X, Changquan L and Min L (2012) Ethanol extract of *Portulaca oleracea* L. protects against hypoxia-induced neuro damage through modulating endogenous erythropoietin expression. *J Nutr Biochem* **23**: 385-91.

Yadhav S, Irfan M, Ahmed A and Hayat S (2011) Causes of salinity and plant manifestations to salt stress: a review. *J Environ Biol* **32**: 667-85.

Yazdanshenas H, Nasiri M and Tavili A (2015) Effect of different physicochemical treatments on seed dormancy of medicinal herbs (*Portulaca oleracea* L.). *J Med Plant Res* **9(2)**: 72-80.

Zimmerman C A (1976) Growth characteristics of weediness in *Portulaca oleracea* L. *Ecol* **57**: 964-74.

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