Medicinal plants are essential natural resource which constitutes one of the potential sources of new products and bioactive compounds for drug development (Gangwar et al., 2010). It is estimated that 60% of the world population and 80% of the population of developing countries rely on traditional medicines, mostly plant drugs, for their primary health care needs (Shrestha and Kunwar, 2003; Das and Mondal, 2012). India has one of the richest gene pools of the medicinal plants in the world (Kamboj, 2000). Out of the 17000 species of higher plants in India, about 7500 are known for medicinal uses, which comprise a considerable proportion of total flowering plants (Shiva, 1996). The Indian Himalayan Region (IHR), designated as one of the global biodiversity hot spot, harbors plant diversity and has traditionally been an important source of medicinal plants (Samant et al., 1998). Medicinal plants are in great demand throughout the Himalayan region, as they are important for traditional health care and in large scale collection for trade.

Nested in the Western Himalayas, Himachal Pradesh is a hilly state situated in the Northwest Himalayan region between 30°22’44”N to 33°22’44”N latitude and 75°45’44” E to 79°04’20” E longitude, extends over an area of about 55,673 sq km in Northwestern part of India (Parkash and Aggarwal, 2009). It is much known for its typical topography, large altitudinal range, diverse habitats and socioeconomically important biodiversity (Sharma and Mishra, 2009). It is a rich repository of medicinal and aromatic plants (Chauhan and Khosla, 1988). Out of 3,500 species of the higher plants identified in Himachal Pradesh, there are about 1,500 species of medicinal and aromatic plants (Parkash and Aggarwal, 2009). Himachal Pradesh, a mountainous state, has varied topographic set up of land forms, climatic conditions and soils, which resulted in different vegetation types (Sharma, 2012).

Medicinal properties in the plants are attributed due to secondary metabolites present. Plant secondary metabolites are often referred to compounds that have no fundamental role in the maintenance of life processes in the plant but are important to interact with environment for adaptation and defence. Secondary metabolites also contribute to the specific odors, tastes and colors in plants and are unique sources for food additives, flavors, pharmaceuticals, nutritive and cosmetic purposes. However, formation of these plant
products is influenced by the intrinsic and extrinsic factors leading to qualitative and quantitative changes in chemical composition.

Instant rising demand of plant–based drugs is creating heavy pressure on hilly medicinally important plants growing in wild. Several of these medicinal plant species have slow growth rate, low population densities and narrow geographic ranges, therefore, they are more prone to extinction due to over harvesting (Kala et al., 2006; Jablonski, 2004). To prevent premature extinction of medicinal plants, there is emerging need to develop technologies for their cultivation and conservation. In an attempt of cultivation of medicinally important wild plants under varying climatic conditions, it is important to understand the behavior of plants in diverse stressful growth conditions with emphasis on morphological, physiological and biochemical parameters. In the present study, an attempt has been made to determine the influence of abiotic stresses, i.e., temperature and light stress on morphological, physiological and biochemical characteristics of *Withania somnifera* L.

*Withania somnifera* (L.) Dunal, a prominent herb of lower Himalaya is commonly known as “Ashwagandha”, “Asgandh” and “Winter Cherry”. It belongs to Solanaceae family and has 1250 species. The genus *Withania* is represented in India by *W. somnifera* and *W. coagulans* (Chadha, 1976). Recently a third species *W. ashwagandha* have been reported from Indian germplasm using multi-disiplinary approaches (Mir et al., 2010; Kumar et al., 2011). Within the family Solanaceae, *Withania* belongs to subfamily Solanoideae, tribe Physaleae and sub-tribe Withaninae of which it is the type genus (Olmstead et al., 2008). The specific epithet *somnifera* is a compound of two Latin words ‘somnus’ meaning sleep and ‘fero’ meaning ‘to bear’. Thus the specific epithet alludes to sleep inducing properties of the plant. It is an important medicinal plant that has been used in Ayurvedic and indigenous medicine for over 3,000 years. Ashwagandha roots are a constituent of over 200 formulations in Ayurveda, Siddha and Unani medicine, which are used in the treatment of various physiological disorders. In Ayurveda, *Withania* is widely claimed to have potent aphrodisiac, sedative, rejuvenative and life prolonging properties. Its roots and leaves are used in a number of preparations for their anti-inflammatory, anticonvulsive, immunosuppressive, antitumor, and antioxidant properties besides for promoting vigor and stamina (Atal et al.,
1975; Al-Hindawi et al., 1992; Tripathi et al., 1996; Devi et al., 1996; Bhattacharya et al., 1997; Kulkarni et al., 1999; Furmanova et al., 2001; Li, 2003). Therapeutic value of its roots is considered comparable to that of Panax ginseng and it is often referred to as ‘Indian ginseng” (CSIR, 1976). Moreover, Ashwagandha has a shorter life cycle; it takes only 8 months to reach maturity.

Withania somnifera shows presence of several groups of chemical constituents such as steroidal lactones, alkaloids, flavonoids, tannin etc. which give the plant material values. At present, more than 12 alkaloids, 40 withanolides (withnone, withaferin A, withanolide A,D,H, I, J, K, L,M, WS-I, P, S, sitoindosides, withanolide C and withsomidioenone) and several sitoindosides (withanolide containing a glucose molecule at carbon 27 ) have been isolated and reported from aerial parts, roots and berries of Withania species. The major chemical constituent are withanolides mainly localized in aerial part of plant (Mirjalil et al., 2009). Nine withasteroids have been isolated from Withania somnifera roots. The withanolides are a group of naturally occurring C28-steroidal lactones built on an intact or rearranged ergostane framework, in which C-22 and C-26 are appropriately oxidizeorma six-membered lactone ring. The withanolide skeleton is defined as a 22-hydroxyergostan-26-oic acid-26, 22-lactone.

The isolated pure compounds from plant have gained importance in therapeutic areas (Senthil, 2011) due to the presence of several withanolides and alkaloids (Ray and Gupta, 1994). The roots are the main organ of the plant used therapeutically (Girdhari and Rana, 2007). The biologically active chemical constituents found in abundance are alkaloids (ashwagandhine, cuswhygrine, anahygrine, tropine, etc.), steroidal compounds including ergostanetype lactones, withaferine A, withanolides A-Y, withanamides, withasomniferin-A, withanone, witoindosides (saponins) and glycowithanolides (Matsuda et al., 2001; Ganzera et al., 2003; Misra et al., 2008, 2012). In all 13 Dragendroff positive biochemically heterogeneous alkaloids have been isolated and characterized from its root extracts. The first scientific investigation by Power and Salway (1911) on South African population of the species revealed the presence of withaniol (C_{25} H_{34} O_{5}) in the roots and somnirol (C_{32} H_{44}O_{7}) and somnitol (C_{33} H_{46} O_{7}) in the leaves. Withanolides especially, withanolide A and withanolide D, extracted from root is responsible for cure of neurodegenerative diseases,
such as Alzheimer’s diseases and Parkinson’s disease due to their neuron regenerative properties (Sandeep et al., 2012). Withanolide A, withanolide D and withaferin A are useful in neurologic disorders like convulsions, cognitive function impairment, etc. (Zhao et al., 2002). Most important aspect about withanolides is to find out the optimum condition in which production of compound is maximum and to find out effect of changing environment on the production of the withanolides.

Plants growth, productivity and secondary metabolites are affected by biotic and abiotic factors (Jaleel et al., 2009). Abiotic factors are prime cause and if not favorable decrease growth and productivity by 50 percent (Afsharmanesh, 2009). Synthesis of secondary metabolites in response to environmental factors is a part of an adaptative strategy leading to tolerance of abiotic stresses (Mahmood et al., 2014). Abiotic stress also leads to the morphological and biochemical changes in the plants. It leads to overproduction of reactive oxygen species (ROS), which stimulates formation of highly active signaling compounds capable of triggering production of bioactive compounds (secondary metabolites) that enhances the medicinal value of plant (Pinheiro and Chaves, 2011). Temperature stress has always been a serious problem for the plants. High temperature is one of the most significant abiotic stresses that affect plant growth and development (Ramakrishna and Ravishankar, 2011). It results in reduced available water in the soil to such critical levels and atmospheric conditions adds to continuous loss of water. Increase in temperature often causes oxidative stress and change in the physiology of the plant system (Jaleel et al., 2008; Ramakrishna and Ravishankar, 2011; Greeshma et al., 2015; Bita et al., 2013; Harvaux and Kloppstech, 2013).

Similarly, low temperature affect plant growth and productivity. Plants growing in low temperature conditions adapt by adjusting their metabolism during autumn, increasing their content of a range of cryoprotective compounds to maximize their cold tolerance (Ramakrishna and Ravishankar, 2011). During over wintering, plant metabolism is redirected toward synthesis of cryoprotectant molecules such as sugar alcohols (sorbitol, ribitol, inositol), soluble sugars (saccharose, raffinose, stachyose, trehalose), and low-molecular weight nitrogenous compounds (proline, glycine). Cold stress increases phenolic production...
and their subsequent incorporation into the cell wall either as suberin or lignin (Weidner et al., 2014). Lignification and suberin deposition are also shown to increase resistance to cold temperatures.

Another important factor that cause stress to plant is light that affect morphology and physiology of plant. Light stress refers to the detrimental effect that exposure to insufficient or excess levels of light can have on plant function and development. Whereas exposure to insufficient light limits photosynthetic activity, exposure to excess light energy can damage the photosynthetic apparatus. Photoperiodism is the response of plants to the relative lengths of light and dark periods within a 24-hour cycle. Plant growth and development processes that are affected by photoperiod include flowering, vegetative growth, internode elongation; tuber, rhizome and bulb formation; sex expression; the formation of pigments; fruit set, leaf fall, dormancy, etc. (Mitrović et al., 2007). Variations in photoperiods has also been found to have significant effect on the secondary metabolites production (Ramakrishna and Ravishankar, 2011). Schopfer and Brennica (1999) viewed that each plant species has a specific tolerance range for the light intensity in which their growth is possible. Isolation below that range will not provide enough energy to drive photosynthesis to maintain their metabolism and excessive light damages the organisms due to high level of UV radiation.

It has been time and again proved that abiotic stress affect the chemical composition and survival of plants (Atkinson and Urwin, 2012). The temperature stress can affect secondary metabolites and other compounds that plants produce, which are usually the basis for their medicinal activity (Zobayed et al., 2005; Salick et al., 2009). Generally when plants are stressed, secondary metabolites production may increase because growth is often inhibited more than photosynthesis, and the carbon fixed not allocated to growth instead allocated to secondary metabolites (Mooney et al., 1991). Several studies have examined the effects of increased temperatures on secondary metabolite production of plants, but most of these studies have contradictory results (Jochum et al., 2007). Some report that secondary metabolites increase in response to elevated temperatures (Litvak et al., 2002), while others report that they decrease (Snow et al., 2003). As such the responses of secondary chemicals to increased high temperature and cold stress are less well understood, although, an increase
in volatile organic compounds has been generally detected in case of former (Loreto et al., 2006). However, it is hypothesized that the warming temperature, cold and light stress will alter growth cycles of plants and active constitutes of the plants may change due to physiological changes (Chaturvedi et al., 2007). Therefore, studies on abiotic stress in medicinally important plant of the Himalaya needs greater attention to understand the underlying phenomenon. For long-term supply of quality raw material to pharmaceutical industries and effective use of medicinal plants for curing ailment, studies on the effect of abiotic stress on plant secondary metabolic production and composition become essential and in the present study Withania somnifera has been selected as a plant to see the effects of light and temperature stress on its growth and secondary metabolites.

In addition to medicinal properties contributed by W. somnifera, it has potential to check weeds. In the Himalayan ecosystem one of the challenging issue is to control weeds which is a threatening problem for plant diversity. Allelopathy is a pragmatic approach for sustainable weed management. Allelopathy is the suppression of one species by another species due to release of chemicals, both negative and positive aspects included in this phenomenon (Kabir et al., 2010). Every aspect of allelopathy is interlinked with allelochemicals, which are secondary metabolites, produced by the plants as the byproducts of their metabolic processes (Levin, 1976). The higher concentrations of allelochemicals usually inhibit the growth of recipient plants and soil microorganisms or both. However, they have stimulatory effects at lower concentrations on growth, seedling development, flowering, fruiting and yield (Mallik and William, 2005). These allelochemicals could be extracted from the plants and applied over target weed for getting desirable weed management. Such a herbicidal effect of plants against weeds is less toxic and harmful to ecology. Allelopathic interaction of plants is the need of hour to be used as potentially safe weedicide (Miri, 2011).

The ecosystems infested with weeds show drastic alterations in their structure and function. Weed species which are the part of dynamic ecosystems originate in natural environment and become hurdle to the crops (Aldrich, 1984; Baker, 1965, 1991). These weeds have some diagnostic features, such as short seed dormancy period, high rate of seed germination, rapid seedling growth, high reproductive ability, life cycle of a short span, very high environmental plasticity, self-compatibility, effective and efficient methods of dispersal.
of propagules, production of different types of novel ecochemicals and tolerance to biotic and abiotic stresses (Baker, 1965), which enable them to grow and survive in varied habitats and inhospitable ecological conditions. As a result of these features, weeds are becoming dominant throughout the world (Holm, 1967; Holm et al. 1977), and threaten the native phytodiversity (Dukes Mooney, 1999; Tilman, 2000; Mc Neely, 2001; Heutte and Bella 2003; Colautti and MacIsaac, 2004; Lee and Klassing, 2004; Jeschke and Strayer, 2005). Allelopathic chemicals have the potential use as bioherbicides and pesticides (Khalid et al., 2002). Knox et al. (2010) showed in Withania somnifera allelopathic potential against Parthenium hysterophorus. In order to evaluate the allelochemical potential of Withania somnifera against weeds of the Himalaya, studies were undertaken to see the influence of water extract on Chenopodium album, Achyranthus aspara, Ageratum coenzyoides and Parthenium hysterophorus.

Chenopodium album L. is a fast growing weedy annual plant of family chenopodiaceae and is one of the robust and competitive weed found abundantly in winter season. The weed is resistant to many herbicides and seed is dispersed by wind, animals, agricultural machinery or manure (Aper et al., 2013). Achyranthes aspera L. is a perennial herb of the family Amaranthaceae. It is an annual, stiff erect herb, and found commonly as a weed throughout India and is one of the noxious weed of Himachal Pradesh. It is a very common weed of waste places and roadsides in India. The weed bears spiny fruits, which provide a great hindrance in movement of both humans and animals (Neeta et al., 2011). Ageratum coenzyoides L. is one such rapidly colonialized invasive alien species of family Asteraceae that has become a troublesome weed over a wide range of ecosystems. It is among the commonest weeds in the Himalayan regions and growing upto the elevation of 2400m in Himachal Pradesh (Kohli et al., 2004; Dogra, 2008); in fact, around 50% of area of Himachal Pradesh is said to be infected with this obnoxious weed (Bhatta,1988). Year-round flowering and the production of large quantities of seed allows A. conyzoides to heavily infest crops, often carpeting the soil where conditions are favorable (Holm et al., 1977). Parthenium hysterophorus, a noxious weed of family asteraceae is widely spread in India. It does not allow any other plant to grow near its vicinity and this is the reason for its
invasive nature. It release partherin which is strongly allelopathic against associated plant species (Riaz and Javaid, 2011).

Despite the high ecological and economic importance of the Himalayan medicinal plants, the effects of abiotic stress on growth of *Withania somnifera* and on secondary metabolite (withanolides) needs to be studied. Further the role of plant as herbicide needs to be looked into. Keeping these facts in mind the present studies are undertaken with the following objectives:

- To study the effects of temperature and light stress on the growth of *Withania somnifera*
- To study biochemical variation and antioxidant defense system in *Withania somnifera* growing under abiotic stress
- To know the effect of temperature and light stress on production of secondary metabolites
- To elucidate herbicidal effect of *Withania somnifera* on the germination and growth of prominent weeds of the Himalaya.