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مدينة الملك عبد العزيز
للعلوم والتقنية
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المجال العام: 1- المجال العام 2- المجال الدقيق

* النباتات الغازية، الحشائش،
* تحسين المراحي

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الكلمات الدالة على البحث (حدد عشر كلمات):
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Name of Submitting Organization: Ministry of Agriculture, College of Food & Agric. Sciences, King Saud University

Directorate: Range and Forestry
Department: Range Development and Improvement
Branch: 

Postal Address: P.O Box: 60850 City: Riyadh Postal code: 11555

Title of Proposal: Management and Control of Argemone sp. in Taif Region

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Research proposal field:*
Major field: Range Management Area: Invasive Plants, Weed Control, Range Improvement
Is this proposal among KACST Announced Priorities: Yes ☑ No
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عنوان المشروع: إدارة حشيشة الأرجيمون ومكافحتها في مراعي منطقة الطائف

ملخص المشروع:

تعد بعض الحشائش الدخيلة في المراعي كنباتات الأرجيمون ذات قدرة تنافسية عالية مع غيرها من النباتات المستوطنة، وتحتاج عملية مكافحتها التكامل بين مجموعة من طرق المكافحة. وتبعد عملية المكافحة المتكاملة خطر الغطاء النباتي السائد في المنطقة التي تنتشر فيها الحشيشة ووضع الخرائط لها للتعريف على اتساع المشكلة وشدة الإصابة بالحشيشة. ومن العوامل المهمة جداً في إدارة المناطق المتضررة بانتشار الحشائش المعرف على طبيعة نمو الحشيشة وسلوكها البيئي وعلاقتها مع نباتات المراعي السائدة في المنطقة وذلك من أجل فهم أبعاد الانتشار وانتشارها. وعند استكمال هذه المعلومات فإنه يمكن رسم استراتيجية الإدارة المتكاملة للحشيشة تمثل على تتبع حركة انتشارها والسيطرة عليها في مواطن انتشارها الجديدة ومكافحتها على نطاق واسع وإعادة تأهيل مناطق المراعي المتضررة بزراعة النباتات الأولى ضمن خطة متكاملة لإدارة المراحي.
## PROJECT SUMMARY

<table>
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<tr>
<td>Ministry of Agriculture &amp; College of Food and Agricultural Sciences, King Saud University, Riyadh, Saudi Arabia</td>
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| Mailing Address: P.O. Box 60855 Riyadh, Saudi Arabia 11555 |

| Principle Investigator: Professor Abdulaziz M. Assaeed |

| Title of Project Proposal: Management and Control of *Argemone* sp. in Taif Region |

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PROJECT DESCRIPTION

2.1 INTRODUCTION

Introducing species into new environment can have devastating effects on ecosystem quality (Van Groenendael et al., 1998). *Argemone* sp. is an example of a noxious weed that has been introduced to Saudi Arabia. This relatively newly introduced noxious weed accounts for the loss of rangeland value in valleys around Taif mountains area. *Argemone* sp. has a tendency to multiply rapidly thereby choking the land, competing other range plant species and reducing the land value. Efforts to control weed infestation are hampered by natural dispersion of seeds and the often extremely long viability these seeds have. Thus determining its rangeland infestation and distribution is essential for planning control measures of this obnoxious and poisonous weed. Traditional means of weed control include the application of expensive herbicides, plowing weeds under the soil (a temporary solution at best), biological control, careful selection and reseeding of valuable grazing plant species, labor intensive pulling efforts, and animal grazing. Without any form of control, noxious weeds can rapidly make viable rangelands worthless.

Studies show that noxious weeds also decrease wildlife forage quality (Medina 1998, Trammell and Butler 1995). Weeds reduce the available forage for livestock. Lym and Messersmith (1987) found that leafy spurge (*Euphorbia esula*), possibly Colorado's most threatening noxious weed, may reduce rangeland carrying capacity by 50-75 percent. Weeds create myriad environmental disruptions. D'Antonio and Vitousek (1992) reported that invasive plant species can drastically alter natural fire regimes. Exotic plants can disrupt ecosystem functions such as nutrient cycling. In one case involving a non-native plant in Hawaii, Vitousek and Walker (1989) determined that introducing a single noxious weed significantly altered the entire functions of an ecosystem. Weeds trigger a decline in ecosystem diversity and an overall reduction in native plant species abundance (Bock et al. 1986, D'Antonio and Vitousek 1992).

Invasions by weeds typically follow anthropogenically established xeric corridors along roads and trails (Brothers 1992). Disturbance to native vegetation is likely to increase invasion susceptibility (Burke and Grime 1996). Hobbs and Heunneke (1992) claim that eutrophication synergistically adds to an ecosystem's vulnerability to weed invasion. Stohlgren et al. (1999) add that a site's proximity to an exotic seed bank, its local species interactions, and resource availability may also contribute to weed proliferation. They concluded that high resource availability in
biological "hot spots," or areas of elevated diversity, increases the risk and rate of weed infestation. Especially in ecologically critical source habitats such as the riparian zones, wet meadows, and aspen groves, small weed patches may expand rapidly revealing a need for early detection and control (Stohlgren et al. 1999).

Controlling these non-native plants begins with an understanding of their extent, their influence upon the landscape and their life histories. Scientists suggest that studies, which include both demographic monitoring and ecological analysis, should be initiated immediately to assess noxious weed invasion trends (Stohlgren et al. 1999, Lodge 1993, D'Antonio 1993). These studies should contain quantitative weed inventories and long-term monitoring programs.

The genus Argemone (Papaveraceae) comprises nearly 28 species (Mabberley 1997). The first documentation of the genus in Saudi Arabia was given by Migahid (1974). Currently, two species are already identified in Saudi Arabia; *Argemone mexicana* L. and *Argemone ochroleuca* Sweet (Chaudhary & Al-Jowaid 1999, Collenete 1985). Both species are distributed in the western and southern parts of the Kingdom, the former being unintentionally introduced from the New World. The history of introduction of *A. mexicana*, now occupying large tracts of deteriorated rangelands in Asir region, is not traceable. *Argemone ochroleuca* is most widespread in Taif area (Shorbaji and Abidiain 1999). The two species are growing in almost all types of soil and at different climatic conditions. In addition, all stages of growth can be observed in the same area at the same time of the year. Word-wide, *Argemone* spp. has been classified as a weed behaving plant in some countries, as a common weed in others and as a principle weed in several countries with serious infestation in Pakistan, India and Tanzania (Holme et.al. 1979). Spread of Agremone is thought to be related to human activities such as site disturbance and overgrazing. Shanmughavel (1995) attributed invasion of *A. mexicana* into a forest rangeland to heavy grazing. The result is a total loss of rangeland carrying capacity and biodiversity.
2.2 REVIEW OF LITERATURE

2.2.1 Inventory and Mapping

Inventory comes first in all integrated weed management programs. Identifying weeds and conducting an inventory require considerable technical skills and can be time consuming but are necessary. The goal is to determine and record the weed species present, the area infested, the density of the infestation, rangeland under threat of invasion, soil and range types and other site factors pertinent to successful management of weed-infested rangeland. Inventories can be conducted by field surveys, aerial photography and by using geographic information systems (GIS).

Information from an inventory should be incorporated into a map that shows the location, type and size of weed infestations. Accurate mapping is important in developing a land use plan and in evaluating the success of a weed management program.

Using modern GIS, and Global Positioning System (GPS) tools, weed control supervisors have unprecedented ability to manage a weed control program. No one wants to spend more money on herbicides and other control methods than they have to. By using GPS and GIS weed control agencies can accurately track the location and magnitude of weed infestation and make better decisions as to the resources allocated to deal with the problem. They can target specific remedies to specific areas and monitor the relative success of their programs by revisiting those sites year after year to see if the square footage and relative density of weed infestation is being reduced and by how much.

2.2.2 Ecology of Argemone

Phenology, floral biology and seed dispersal of Argemone have been studied in India (Kaul 1969). Germination behavior of A. mexicana seeds was also studied by Sarma (1983, 1988). He found that the seeds germinated only at low temperature (8°C) and 100% germination was obtained with the ‘continuous dark’ treatment. Karlsson et al. (2003) concluded that the majority of Argemone seeds normally do not germinate during the first season, but are maintained in the soil seed bank for several years.

Like many other weeds, A. mexicana is also known to be allelopathic and retards the germination of mustard, jower, ragi, wheat and cucumber (Leela, 1981). After large-scale sampling of transects in wheat fields, Rawson & Bath (1980) came
to the conclusion that *A. mexicana* mainly colonizes areas where wheat stands are poor or where there are gaps in wheat seeding. They also reported that *A. mexicana* could be eliminated from wheat stands, by using higher seeding rates for wheat, but this resulted in reduced yield per hectare.

Apart from the above, not many studies aimed at understanding the ecology of the *Argemone* sp. and its effective control is available in natural habitats. The Saudi Arabian *Argemone* weed problem also does not seem to have received any serious attention. Practically nothing is known about the extent and the intensity of *Argemone* sp. infestation in the Kingdom and so naturally nothing is also known about the ecotypical variations, ecological preferences, population dynamics, the allelopathic effects, *etc.* of *Argemone* sp. in Saudi Arabia except for a study on the habitat and seed analysis (Hussein *et al.*, 1983). There seems to have had no previous attempts for the control of the weed in the Kingdom.

### 2.2.2.1 Phenological Studies

Phenology is the study of the relationships between various climatic factors and the occurrence of successive stages in the life cycle of organisms (McCarty, 1986). In rangelands, knowledge of the progression of stages of development and growth habits of weeds is important to management plans and thus control measures can be applied more effectively (Blaisdell, 1958; West and Gasto, 1978; McCarty, 1986). To our understanding, no work is available on *Argemone* sp., yet this information is very crucial in determining the most susceptible stage(s) of growth for weed control.

### 2.2.2.2 Rooting Patterns

Studies of plant responses to drought, fertility, competition and other environmental conditions depend entirely upon a thorough knowledge of root habits. These include depth of penetration, extent of branching, distribution through the soil profile, rate of growth, ratio of roots to shoots and other characteristics which determine the absorptive ability of the plant and hence its interactions with other species in the plant community (Cook and Stubbendieck 1986).

### 2.2.2.3 Seed Dispersal

Successful regeneration by a plant depends upon its seeds being dispersed to places where conditions are suitable for germination and seedling establishment. Places where such conditions are met have been called “safe sites” (Harper 1977). Each species has its own characteristic requirements in this respect, so that a safe
site for one species may be unsafe for another. The different patterns of dispersal found in different plants are presumably the result of their adaptation to certain environments. This does not necessarily involve maximizing the distance over which the seeds travel, as suitable safe sites might be more readily available in the vicinity of the parent plant than further away, as is often the case with desert plants (Ellner and Shmida 1981). Knowledge about the dispersal patterns of Argemone sp. will help in understanding the mechanism by which it advances into areas previously unoccupied.

2.2.2.4 Soil Seed Bank

Soils contain many viable, but ungerminated seeds produced either in the most recent reproductive event or in previous years. Seed bank size depends on seed inputs and longevity of viable seeds (Roberts, 1981). Venable and Brown (1988) suggested that the seed bank might act as a propagule to reduce the probability of species extinctions. Knowledge of the seed bank dynamics is essential to understand the turnover rate, and the seeds proportion of a species in a seed bank that could persist more than one year (Hyatt and Casper, 2000). In addition, seed bank might give a better prediction of what species may dominate a plant community after disturbance (Nobel and Slayter, 1980). Karlsson et al. (2003) concluded that the majority of Argemone newly produced seeds do not germinate readily but enter the soil seed bank and may persist for several years.

2.2.2.5 Seed Germination

When seeds survive the various hazards, which they face during ripening, dispersal and dormancy phases, they become ready to germinate provided they encounter the appropriate environmental cues. Each species has its own characteristic set of germination requirements. The responses shown by seeds to the great variety of conditions to which they are subjected to, can be regarded as adaptations for maximizing the likelihood of surviving in unpredictable environment. To accomplish maximum survival, the seeds need to develop survival mechanisms, which eliminate chances of extinction of a species. In this regard, Argemone seeds go through dormancy and do not germinate readily when climatic conditions are not suitable for germination and seedling survival (Karlsson et al. 2003).
2.2.2.6 Competition and Allelopathic Interactions

Competition is defined as an interaction between individuals, brought about by a shared requirement for a common resource in a limited supply leading to a reduction in the survivorship, growth and/or reproduction of the competing individuals concerned (Begon et al. 1990). Interspecific competition (competition between different species) can be seen as a form of density dependence in plant populations where an individual of the competing species has a greater or lesser effect on the target species than does an individual of the target species itself. Interspecific competition has been demonstrated in many pot and glasshouse experiments (Firbank and Watkinson 1990, Shipley 1994, Assaeed and Al-Doss 2001). However, field experiments involving the manipulation of species density are necessary to determine the role of competition in shaping the structure of the real plant communities. Field experiments on competition are less precise than controlled ones, therefore careful planning of these experiments and interpretation of their results are necessary. In general, several field experiments on a wide variety of plant communities have indicated that increased densities of concerned species decreased the performance of individuals of the target species (Goldberg and Barton 1992, Gurevitch et al. 1992). Results of competition experiments are very helpful in planning for grazing management and range restoration.

Allelopathy is defined as the inhibitory or stimulatory reciprocal biochemical interactions among plants (Rice, 1984). Newman and Rovira, (1975) proposed two modes of action for allelopathy. First, the synergistic effect between competition and allelopathy may provide the producer of phytotoxins with an advantage over its competing species. The second mechanism is “self-balancing negative feed-back” whereby stressed plants produce more allelochemicals to suppress the growth of immediate vegetation, thereby providing enough reduction in competition to remain in the community. This assumes that allelochemicals are released from intact living plant materials such as roots.

Water extracts from herbage of several allelopathic species have been reported to adversely affect seed germination of recipient plants (Kalburtji and Mosjdis, 1993a; Assaeed and Al-Doss, 1997) and seedling growth (Roder et al., 1988; Kalburtji and Mosjdis, 1992; Assaeed and Al-Doss, 1996). Root exudates from Lespedeza cuneata have also been reported to reduce the early seedling growth of its associate grasses but had no effect on seed germination. (Kalburtji and Mosjdis, 1993b). Assaeed (2003) reported that root exudates from Artemisia monosperma
reduced seedling survival of some range plant species but biomass of survived seedlings was not affected.

**2.2.3 Effect of Protection and Controlled Grazing on Vegetation**

Biotic and abiotic factors and their interaction influence plant population dynamics (Harper, 1977). In rangelands, herbivory is considered one of the most important biotic factors that play a major role in plant community dynamics through exerting both direct (grazing) and indirect (modifying competitive relationships) effects (Crawley, 1983; Whitham et al., 1991; Trlica and Rittenhouse, 1993). Herbivory influences a plant competitive ability through changing its ability to acquire limited resources and/or eliminating the plant as a competitor (Louda et al., 1990).

Heavy grazing is well documented to have adverse effects on both livestock performance and vegetation (Holechek et al. 1998). Heavy grazing have lead to an increase in invasive species such as Prosopis glandulosa in Chihuahuan Desert (Drewa et al. 2001), Bromus tectorum in US Great Plains (Mack 1981, Floyd et al. 2003) and Rhazya stricta in Saudi Arabia (Assaeed, 1996). Light grazing or even complete protection from grazing is seldom recognized to improve vegetation (Holechek and Stephenson 1983, Hughes 1983, Atwood and Beck 1987). Protection from grazing does not improve weed-infested rangelands. Hughes (1980) found that protection from grazing for 25 years increased plant density of Artemisia tridentata by 30-40%. To our knowledge, there are no information on the effect of grazing management on on the Argemone infestation.

**2.2.4 Weed Control Planning and Implementation**

Planning and implementing an integrated weed management strategy is an important phase of weed management. Problems and solutions must be identified and prioritized and an economical plan of action should be developed to provide direction for implementing the integrated weed management (IWM) program. Integrated weed management includes preventing encroachment into rangeland that is not infested, detecting and eradicating new weed introductions, containing large-scale infestations, controlling large-scale infestations using an integrated approach, and often, revegetation. The key components of any successful weed management program are sustained effort, constant evaluation and the adoption of improved strategies.
2.2.5 Integrated Weed Management

Weed encroachment can be prevented by limiting weed seed spread, minimizing soil disturbance and maintaining vigorous and competitive range plants. Small weed infestations can be eradicated, and small-scale satellite infestations should be persistently treated with herbicides. Large-scale infestations must be contained using herbicides along infestation borders. Depending on site conditions, the appropriate combination of herbicide, biological control agents, and grazing management can reduce weed populations and weed seed production in large-scale infestations. Competitive range plants can be maintained with proper grazing rotations that allow plants to recover vigor after disturbance. Monitoring will detect changes in weeds and desirable plants as an integrated weed management plan is implemented. Management adjustments can be made to address the changing conditions. A key component of any IWM program is sustained effort, constant evaluation, and the adoption of improved strategies.

Different classes of herbicide will be used in laboratory experiment to select the best selective herbicides on *Argemone* sp. Surface tillage and herbicides residues effects on the rangeland species will be determined in small scale as a primary step of large-scale control.

2.2.5.1 Large-scale Weed Control

Most successful large-scale weed control programs are completed in a series of steps. Weed control areas should be divided into smaller units to make them more manageable. Weed control should be carried out unit by unit at a rate compatible with economic situations.

Containment programs restrict the encroachment of large-scale weed infestations. Studies have shown that containing weed infestations that are too large to eradicate is cost effective because it preserves neighboring un-infested rangeland and enhances the success of future large-scale control programs. Containing a large-scale infestation requires using preventative techniques and spraying herbicides on the border of weed infestations to stop the advancing front of weed encroachment.

2.2.5.2 Biological Control

Biological control is the use of animals, fungi, or other microbes to feed upon, parasitize or otherwise interfere with a targeted pest species. Successful biological control programs usually significantly reduce the abundance of the pest, but in some
cases, they simply prevent the damage caused by the pest (e.g. by preventing it from feeding on valued crops) without reducing pest abundance (Lockwood 2000). Biological control is often viewed as a progressive and environmentally friendly way to control pest organisms because it does not leave any chemical residues that might have harmful impacts on humans or other organisms, and when successful, it can provide essentially permanent, widespread control with a very favorable cost-benefit ratio (DeLoach 1991). However, some biological control programs have resulted in significant, irreversible harm to untargeted (non-pest) organisms and to ecological processes. Of course, all pest control methods have the potential to harm non-target native species, and the pests themselves can cause harm to non-target species if they are left uncontrolled. Therefore, before releasing a biological control agent (or using other methods), it is important to balance its potential to benefit conservation targets and management goals against its potential to cause harm.

Organisms used to feed on, parasitize, or otherwise interfere with targeted pests are called biological control agents. There are several general approaches to using biological control agents:

1. ‘Classical’ biological control targets a non-native pest with one or more species of biological control agents from the pest’s native range;
2. ‘Conservation’, ‘Augmentation’ and ‘Inundation’ approaches maintain or increase the abundance and impact of biological control agents that are already present, and in many cases native to the area;
3. New Association’ or ‘Neoclassical’ approach targets native pests with non-native biological control agents.

2.2.5.2.1 Classical Biological Control

Classical biological control is by far the most common approach for plant pests. Conservation and augmentation approaches show great promise on their own and especially for enhancing the impacts of classical biological control and other weed control measures as researchers and managers focus on managing to maximize native biological diversity in invaded ecosystems (Newman et al. 1998). The approach to be used in this project is the classical biological control; hence it will be discussed in detail.

In classical biological control, it is hypothesized that some non-native plants become invasive, superabundant and damaging, at least in part because they have escaped the control of their ‘natural enemies’, the herbivores and pathogens that
checked their abundance in their native ranges. Classical biological weed control is applied by locating one or more herbivore and/or pathogen species from the weed's native range and introducing them so they can control the pest in its new range. These herbivores and pathogens are carefully selected and screened to determine if they will attack other non-target plant species. Successful classical biological control programs result in permanent establishment of the control agent(s) and consequent permanent reduction in the abundance or at least the damaging impacts of the weed over all or in part of its introduced range. Classical biological control is not expected to eliminate the pest species completely and it often takes years or even decades after the initial release of control agents before their effects are obvious. Classical biological control programs may fail for a variety of reasons. Some biological control agents never establish, or it may take repeated releases to establish viable populations. Some biological control agents may become established, but then have little or no detectable impact on the targeted pest (Greathead 1995).

Some of ‘classical’ biological control's greatest strengths are that once an agent is established, it will persist ‘forever’ and it may spread on its own to cover most or all of the area where the pest is present, generally with little or no additional cost. On the other hand, these strengths can become great liabilities if the agent also begins to attack desirable species (Pemberton1985; Lockwood 1993, 2000; McEvoy and Coombs 2000). Because of this, weed biological control researchers take pains to locate and use agents that are specific to the targeted weed and will not attack other “important” plant species. This screening process contributes to the high cost and long time required for the discovery, testing, and approval of new biological control agents.

A key part of the screening process, in classical biological control, is host-testing, wherein potential control agents are given the opportunity to feed on a variety of crop species and native plants, including those most closely related to the targeted pest. No-choice tests isolate the potential control agent with one or more native species for feeding and/or egg-laying, so that if they do not use the native(s) they will die or fail to reproduce. Other tests give the proposed biological control agent a choice between feeding or reproducing on the targeted pest and non-target native species. Today, proposed biological control agents are screened for their ability to feed and reproduce on several to many native species, but it is still impossible to test all native species. For programs targeting species such as leafy spurge (Euphorbia esula) with many native congeners (over 100 native Euphorbia spp. in the U.S.), it is not even possible to test all the native species in the same genus. In addition, the
tests cannot determine whether the control agents will adapt or evolve over time so that they will become more able or willing to feed on native species (McEvoy 1996).

McEvoy and Coombs (2000) claimed that the potential effectiveness of candidate biological control agents has been given too little attention in the selection process. They argue that ten or more species of biological control agents have been released against some weeds. Since there is some risk that each species will have unintended harmful impacts, the overall risk increases with the number of species released. In addition, some relatively ineffective species may actually interfere with and lessen the impacts of species that might be effective in their absence. Therefore, McEvoy and Coombs (2000) urge biological control practitioners to instead strive to release the minimum number of agents required to control the weed by first identifying and releasing only those species most likely to be effective. They advocate efforts to systematically identify traits common to successful control agents and the types of insects the target weed is most likely to be vulnerable to, based on its lifecycle and physiological attributes. Similarly, Louda et al. (1997) and Nechols (2000) advocate increased consideration of the interactions a candidate biological control agent is likely to have, with control agents and other organisms that are already present in the system.

Use of formal risk assessment procedures, efforts to minimize the number of agents released against a given target, and requiring follow-up studies designed to assess impacts on target and non-target species in order learn how to improve later programs would answer many of the concerns of conservation biologists (Miller and Aplet 1993; Simberloff and Stiling 1996; Strong and Pemberton 2000). Australia has a legislative framework that requires a formal risk assessment before releases are granted which is designed to minimize non-target impacts (McFayden 1998; Withers et al. 2000) and New Zealand is in the process of developing protocols for assessing and balancing risks and benefits of proposed introductions (Barratt et al. 2000).

Successful classical biological control projects reduce the abundance or impacts of the targeted pests to acceptable levels across large areas. There have been excellent post-release studies on Klamathweed (*Hypericum perforatum*) and tansy ragwort (*Senecio jacobaea*) biological control agents (Holloway and Huffaker 1951; Huffaker and Kennett 1959; McEvoy 1985; McEvoy and Rudd 1993; McEvoy et al. 1990; 1991; 1993), which provide quantitative information about reductions in the abundance of the target weeds. In each case significant reductions in the density of the targeted weeds were recorded after biological control agents were introduced.

Impacts of the four insects released to control purple loosestrife in the U.S.
and Canada have also been monitored. The leaf feeding beetles *Galerucella pusilla* and *G. calmariensis*, first introduced in 1992, have apparently reduced purple loosestrife stands at several sites (Blossey et al., 1994; Scudder and Mayer, 1998). It was found that at high *Galerucella* densities (200 larvae/plant), plants were entirely stripped of all green tissue and seed production was prevented (Butterfield et al., 1996). Even at lower beetle population densities, adult and early larval feeding destroyed meristematic regions thus, preventing normal growth. Nonetheless, it is not yet clear whether this feeding is significantly reducing the root biomass of established loosestrife stands.

Unfortunately, studies of the impacts of other biological control agents released against weeds have been extremely rare. For example, a recent paper by Lym and Nelson (2000) on impacts of two flea beetle species released against leafy spurge is the only published study that quantifies population level impacts of any of the 13 insect biological control species released against this widespread pest in the U.S. and Canada. They found that both fleabeesles, *Aphthona lacertosa* and *A. czwallinae* reduced leafy spurge stem densities by about 65% up to 16 m from initial release sites within 3 to 5 years. A mixed population of both Aphthona species reduced stem densities by over 95% within 4 years after release. Establishment and rate of spread of these insects were similar regardless of the number of insects released initially.

Examples of weed biological control projects in North America that are regarded as having successfully reduced the abundance of the targeted species to acceptable levels include those to control Klamathweed (*Hypericum perforatum*), tansy ragwort (*Senecio jacobaea*), and alligatorweed (*Alternanthera philoxeroides*). Programs to control leafy spurge (*Euphorbia esula*) and purple loosestrife (*Lythrum salicaria*) appear to be on their way to at least partial success (Anderson et al. 2000). On the other hand, programs to control Canada thistle (*Cirsium arvense*), spotted and diffuse knapweed (*Centaurea maculosa* and *C. diffusa*) and yellow starthistle (*Centaurea solstitialis*) have not yet been successful, despite years of effort and releases of several insect species against each one.

Although biological control agents can be extremely selective against pest species, there is some risk that they may also attack desirable species. For example, the weevil *Rhinocyllus conicus* which was first introduced to North America to control non-native thistles in the 1960s has been documented attacking and significantly reducing seed set and reproduction of the untargeted native thistle species *Cirsium canescens* (Platte thistle) and *C. undulatum* (wavy-leaf thistle) (Louda et al. 1997;
Louda 2000). Earlier studies determined that *R. conicus* feeds on several native *Cirsium* species, but they had not indicated whether or not this was causing population level impacts (Turner et al. 1987). Similarly, the cinnabar moth (*Tyria jacobaea*) that was introduced to control tansy ragwort (*Senecio jacobaea*), is known to attack native *Senecio triangularis* in Oregon (Diehl and McEvoy 1990).

Another example of a biological control agent causing significant damage to native plants involves the cactus moth, *Cactoblastis cactorum*, which was used with spectacular success to control several introduced species of *Opuntia* in Australia and several Caribbean islands, and then spread inadvertently to Florida where it is damaging native *Opuntia* species (Habeck and Bennett 1990). Two species it has already attacked in Florida are rare, and one of them, *O. spinosissima*, has just one known U.S. population containing a total of less than a dozen plants. By 1997, *C. cactorum* had spread north to Jacksonville, Florida, and there are concerns that it will spread further north and west across the Gulf coast into Texas, and beyond to the southwestern U.S. and northern Mexico, where there are numerous native *Opuntias*, some of which are rare or are of economic importance (Habeck and Bennett 1990; Stiling and Simberloff 2000). Ironically, one way to address the threat posed to North American *Opuntia* species may be by releasing biological control agent(s) to control *C. cactorum*.

Recent research indicates that biological control agents may also have undesirable indirect impacts on non-target plants and animals. Callaway et al. (1999) found that when biological control insects (knapweed root moth; *Agapeta zoegana*) fed on the roots of spotted knapweed (*Centaurea maculosa*), neighboring Idaho fescue (*Festuca idahoensis*) plants actually did more poorly than when grown with unattacked *C. maculosa*. They also found that knapweeds fed on by another non-native root feeder (*Trichoplusia ni*) had smaller root systems and exuded more total sugars than knapweeds protected from attack. It is hypothesized that moderate herbivory stimulated compensatory growth and production of defense chemicals that had allelopathic effects or otherwise altered the competitive relationship between the invasive knapweed and the native bunchgrass (Pearson et al. 2000). A different study in west-central Montana found that two spotted knapweed biological control agents, the gall flies *Urophora affinis* and *U. quadrifasciata*, were the primary food item for deer mice (*Peromyscus maniculatus*) for most of the year and made up 84-86% of their winter diet (Pearson et al. 2000). These deer mice tended to select microhabitats with high or moderate densities of knapweed when the gall flies were in their larval phase, but switched to sites dominated by native prairie after the gall flies
emerged and were unavailable. In turn, deer mouse predation on the gall flies was so strong that the authors speculate it may prevent the flies from controlling spotted knapweed populations.

Classical biological control has many benefits and risks when used in conservation areas. Many conservation biologists have what might be called a “green light - yellow light” attitude towards the use of classical biological control against natural area weeds. On the one hand, classical biological control gets a ‘green light’ or ‘go ahead’ since it has the potential to be one of the most selective, powerful and cost-efficient tools available for control of invasive plants. It is an attractive option in natural areas particularly because of its potential for specificity and its ability to act over huge areas for the long term with little or no cost after the initial research and release(s) of agents. In addition, many find biological control preferable to the use of herbicides because of the danger these compounds may pose to other organisms, including humans, especially if they enter water supplies or otherwise move from sites of application. Biological control may be the only affordable option capable of bringing certain widespread natural area weeds like tamarisk (*Tamarix* spp.), melaleuca (*Melaleuca quinquenervia*) and purple loosestrife (*Lythrum salicaria*) under control over large areas. As a result, many land managers and researchers have urged that particular widespread and difficult to control pests, be targeted for classical biological control.

On the other hand, biological control gets a ‘yellow light’ (some might even say a ‘red light’) for caution largely due to concerns that biological control agents may attack and damage populations of non-target native species. Natural area managers are typically concerned with the health and growth of a wide variety of organisms, far more species than most farmers, ranchers or foresters. If a biological control agent does in fact attack any native non-target species, its persistence and ability to spread to areas far from release sites become serious liabilities. It is widely believed that the potential for harm to non-target organisms can be decreased with improved host-testing and risk reduction protocols for biological control. While biological control offers great promise, it will provide long-term benefits to natural areas and biodiversity preservation only if it is practiced carefully and its potential risks are fully recognized and addressed. In Australia, biological control programs for natural area and wildland pests are better supported and regulated, and as a result, are expected to be more successful (McFayden 1998; Withers et al. 2000).

There is also concern about releases of classical biological control agents among some conservationists precisely because the agents are themselves non-
native introductions. In some cases the agents may carry additional non-native parasite and commensal species. There has been at least one case in the past decade in which a biological control release unintentionally included a second non-native look-alike species that has now become established. Intentional introductions of non-native classical biological control agents may, however, contribute to global biodiversity by significantly reducing large populations of targeted non-native organisms that would otherwise reduce or threaten populations of native species.

Of course, it must be recognized that all courses of action against pest organisms, including that of taking no action, carry some risk to valued, non-targeted organisms. If no action is taken, the pest may continue to spread and reduce or eliminate valued native species, and in the worst cases, drastically alter community and ecosystem functioning (Vitousek 1986; Vitousek et al. 1987; Whisenant 1990). Pesticide use may directly kill valued species or indirectly impact them by reducing food supplies, eliminating cover or otherwise altering the environment. Mechanical methods often disturb the soil and destroy vegetation enabling ruderal plants and “weedy” pioneer species to gain a foothold. With all control methods, there is also the risk that when one pest is eliminated another will merely take its place, and that the infestation is merely the symptom of a more fundamental problem. For example, in Douglas County, OR, Klamathweed populations were sharply reduced by biological control agents only to be replaced by tansy ragwort (Senecio jacobaea), which was in turn sharply reduced by biological control agents only to be replaced by Italian thistles (Carduus pycnocephalus) (Coombs 1991). Coombs believes that while successful biological control agents will likely be found for these thistles, they will only be replaced by another pest and then another in an endless substitution series, unless cultural practices in the area are changed.

2.2.5.2.2 Conservation Biological Control

Conservation biological control is usually defined as actions that preserve, protect, or promote the abundance of organisms that may keep the abundance of another, pest organism in check (Ehler 1998). Usually this entails modifying the environment in ways that promote the abundance and/or impact of native or already established non-native organisms. To date, this approach has received relatively little attention for weed control. Studies to understand and enhance the impacts of two native insects species, and especially the weevil Euhrychiopsis lecontei on the non-native invasive Eurasian watermilfoil (Myriophyllum spicatum) are an exception to this (Creed and Sheldon 1995; Sheldon and Creed 1995. The weevil actually favors the non-native
M. spicatum over its native host M. sibiricum but nonetheless it effectively controls M. spicatum only in some situations (Sheldon and Creed 1995; Solarz and Newman 1996). Researchers are currently studying the factors that limit the weevil’s effectiveness in hopes of finding ways to enhance it. Competition from native aquatic plants, refugia from bluegill predation for the weevils in dense beds of native plants, and adequate shoreline overwintering habitat may all play a role in the success of the weevil (Newman et al 1998). These and other factors could be manipulated to enhance control of Eurasian watermilfoil. There may be great gains to be made by focusing more attention and resources on conservation biological control approaches to management of weeds in conservation areas and other wildlands (Newman et al 1998). Native insects and pathogens will work only against some invasive plants and only in some situations but they are also less likely to have unintended harmful effects on non-target species that exotic biological control agents, herbicides and other control methods have. In addition, the conservation approach can help enhance the impacts of non-native biological control agents that were intentionally or unintentionally introduced, perhaps in ways that will help reduce the necessity to use other, riskier control methods.

2.2.5.2.3 Inundative Biological Control

The "Inundative" or "augmentative" biological control approach uses mass releases of predators, herbivores, or pathogens, that are already present but whose effects on the target are normally limited by their ability to reproduce and spread. To date, this approach has been more commonly used against insect pests. “Inundative” biological control agents that are non-native and/or not target specific, such as the grass carp (Ctenopharyngodon idella) used to control aquatic vegetation, may be sterilized or otherwise rendered incapable of establishing permanent populations before they are released. Because they either fail to establish or do not remain abundant enough to control the pest, they must be reared and released again each time the pest population erupts. There have, however, been instances in which mistakes or back-mutations allowed purportedly sterile control agents to establish permanent wild populations.

2.2.5.2.4 New Association (or Neoclassical) Biological Control

The “new association” technique, in which non-indigenous control agents are introduced to control native pests, was first proposed by Pimentel in 1963. Later article by Hokkanen and Pimentel (1989) provided more support for this technique. This
inspired programs to develop biological control for native organisms ranging from grasshoppers to mesquite (*Prosopis glandulosa* and *P. velutina*) and broom snakeweed (*Gutierrezia sarothrae*) (Carruthers and Onsager 1993; DeLoach 1981; 1985). Proponents of these programs seek agents that are host-specific and capable of reducing populations of species regarded as economic pests to acceptable levels. They point out that successful programs could result in great reductions in pesticide use and concomitant environmental damage. This technique has been tried in several instances in North America, most recently with the release of an Australian fungal pathogen to control native grasshoppers in North Dakota and Alaska (Carruthers and Onsager 1993). An earlier case, the highly successful program to control native prickly pear cacti *Opuntia littoralis* and *O. oricola* with the introduced cochineal insect *Dactylopius opuntiae*, is notable for two reasons: it was begun in 1939 long before Pimentel's proposal and; it was carried out on Santa Cruz Island on land now managed as a preserve by The Nature Conservancy (Goeden and Ricker 1981). There is some evidence that *Pistia stratiotes*, or water lettuce, may be native to the southeastern U.S. and it has also been the target of several foreign biological control introductions (Julien 1992). *Phragmites australis* is also native to North America and is currently the subject of research designed to identify and screen organisms from other continents where it is also native that might reduce its abundance here. It has been suggested that non-native biotypes of *Phragmites* have been introduced to North America and are behaving aggressively so a program to control this species does not necessarily fit neatly into the ‘classical biological control’ or ‘new association’ categories.

Many native species targeted for control by exotic species, however, are ecological dominants in natural as well as in disturbed environments (Pemberton 1985). Examples include the mesquites (*Prosopis glandulosa* and *P. velutina*), creosote bush (*Larrea tridentata*), and big sagebrush (*Artemesia tridentata*). As dominants, these species are of critical importance in natural areas. Significant reduction in their populations would alter the communities they dominate, perhaps rendering the communities unrecognizable and useless as habitat for many other native species. Such damage has been caused by forest pests such as chestnut blight and Dutch elm disease, which were accidentally introduced to North America.

Other native species that have been targeted such as *Astragalus wootonii* are less conspicuous, but nonetheless important members of native communities (Pemberton 1985). Some of these plants may provide the main source of support for certain herbivores and pollinators. Lockwood (1993) noted that control agents considered for release on pest grasshoppers would likely attack non-target native
grasshoppers. He pointed out that one grasshopper species likely to be hit this way, *Hesperotettix viridis*, feeds on and may limit populations of native snakeweeds (*Gutierrezia* spp.) that are considered range weeds. Thus, an inadvertent effect of this program could allow invasive weed population in rangelands to expand. Lockwood’s (1993) cost/benefit analysis of the grasshopper control program suggests that control agents will likely be greater liabilities than assets, even on rangelands. Their impacts on natural areas, where native insect diversity is valued, would likely be even more detrimental. Pemberton (1985) and Lockwood (1993) both note that the ability of biological control agents to spread and perpetuate themselves becomes a clear liability when native species are targeted. Control techniques that are more confined in space and time should be used against native pests. This might include other biologically based techniques as well as pesticides, mechanical and cultural methods. Pemberton (1985) and Lockwood (1993) also note that when grazing and other harvest practices promote native pests, alteration of these practices may well be the best way to address the problem.

### 2.2.5.2.5 Other Biologically-based Weed Control Techniques

Compounds derived from several pathogenic organisms have shown promise for use as bioherbicidal agents against wildland pests but development of delivery systems for some has proven difficult (Prasad 1992; 1994). For example, a compound toxic to spotted knapweed (*Centaurea maculosa*) was isolated from cultures of *Alternaria alternata*, a fungal pathogen specific to it (Kenfield et al. 1988; Stierle et al. 1988). The compound, named maculosin, may be produced synthetically and may find use as a species-specific herbicide against *C. maculosa* which infests natural areas across much of the northern U.S. A few other mycoherbicides have been developed and some were marketed for short periods but only one, which controls a vine pest in Florida citrus orchards, was effective enough to be commercially successful. The best known biopesticides have been derived from various strains of *Bacillus thuringiensis* (Bt) and used against insect pests, particularly Lepidoptera (moth and butterfly caterpillars). In the past few years plants that have been genetically manipulated to produce Bt on their own have been released for sale and the subject of intense controversy due to questions about the effects of such widespread presence of this compound in agroecosystems and in human food.

Mixing fungal bioherbicides (also called mycoherbicides) with pesticides can increase or decrease the severity of diseases they cause (Altman and Campbell 1977; Katan and Eshel 1973). Some adjuvants may sharply increase the severity of disease by allowing pathogens to penetrate plants where they otherwise would have difficulty
(Wymore and Watson 1986). Certain growth-regulators have also been shown to enhance the effectiveness of bioherbicides (Wymore et al. 1987). In a few instances it has been found that sunscreens help extend shelf-life of bioherbicides presumably by protecting the active agents from harmful ultraviolet radiation (Morris 1983; Prasad 1994). Prasad (1994) also suggests that the addition of rainfastness agents may enhance the effectiveness of some bioherbicides. Different bioherbicides will probably require different mixtures of additives and different delivery systems to insure maximum effectiveness and these will likely be discovered both by further research and by trial-and-error as more people attempt to use them.

### 2.2.5.3 Integration of Biological Control with Other Control Methods

Although biological control is often seen as an alternative to other methods, particularly herbicides, it can in fact be used in combination with them. Such combinations may interfere with or enhance each other. For example, prescribed fires could sharply reduce populations of biological control agents if lit when the agents are exposed and unable to flee, but the timing, frequency and spatial distribution of the burns might be adjusted so that they do not interfere or harm the agents, and may perhaps even enhance their impacts (Briese 1996). Likewise, mowing and other mechanical treatments can be timed or adjusted to enhance biological control. For example, mowing the thistle *Carduus thoermeri* at the bud or bloom stage significantly reduces populations of the biological control agent *Rhinocyllus conicus*, but mowing later in the season, after the primary inflorescences have senesced, actually enhances control by chopping lateral inflorescences usually missed by *R. conicus* (Tipping 1991). Herbicide applications can also interfere with or enhance biological control. In most cases the interference is indirect and results from the reduction in food supply or other habitat changes caused by herbicide. Such indirect interference can sometimes be mitigated by leaving untreated areas where high populations of the control agent can survive and re-colonize treated areas if and when the weed re-appears there (Haag and Habeck 1991); of course these untreated sites may also provide the weed seed that re-colonizes the treated area! It has been hypothesized that sub-lethal doses of herbicide may make leafy spurge more attractive or nutritious to biological control agents and therefore enhance their impacts. Similarly, application of plant growth retardants such as EL-509 and paclobutrazol can actually enhance the effectiveness of water hyacinth weevils by preventing the plants from outgrowing the damage inflicted by the weevil (Van and Center 1994; Newman at al 1998). Addition of nutrients to an infested site may seem counterproductive, but in some cases it may help by making...
the weed nutritious enough to support rapid population increase of a biological control agent. For example, addition of nitrogen to nutrient poor waters infested by *Salvinia molesta* increased the weed’s acceptability and nutritional quality for two biological control agents, and allowed one to increase to densities sufficient to effect control (Room et al. 1989; Room 1990; Room and Fernando 1992).

### 2.3 PROJECT MAIN OBJECTIVES

The proposed research project is composed of four different areas of work: (i) inventory and mapping of *Argemone* sp. infestation, (ii) ecological studies of the weed, (iii) control practices and (iv) management of *Argemone*. Specific objectives of these different areas of work are stated in their respective places. However, the followings are the general objectives of this project:

1. Determine the distribution and infestation pattern of *Argemone* sp. in Taif Region.
2. Determine the ecological behavior and factors affecting *Argemone* sp. in Taif Region.
3. Determine the best control treatments of *Argemone* sp. in Taif Region.
4. Determine suitable management practices of weed-infested rangelands to combat the weed.
5. Propose a mechanism for the application of results and recommendations of the project.

### 2.4 PROJECT DESIGN

The project consists of four main areas of work. Specific objectives and methodologies are presented below in details.

#### 2.4.1 Inventory

**2.4.1.1 Objectives**

1. Map the noxious weed sites
2. Assess needs for and determine future control methods.
3. Detect movement of *Argemone*.
2.4.1.2 Development of a GIS infestation map

Converting data into information is a very important operation since information is the basis on which a decision regarding a specific issue is made. Development of maps is a very effective means of presenting information, especially in certain circumstances such as weed infestation. Weed infestation within a specific area is a spatially-variable factor which makes it a good candidate to be analyzed to illustrate the magnitude of the problem at different locations of the study area. Moreover, GIS maps can be greatly used to effectively control the problem on hand with the least possible environment contamination by tailoring the rate of herbicide suggested to different requirements of the study area.

Four control-points within the study area will be determined. At each control-point, the antenna of a GPS receiver will be fixed and the location data will be acquired (Lat/Long) to the second. Location data has to be recorded by a laptop computer for at least 2-3 hours. A minimum of four repetitions on four different days has to be conducted while in the field. Location data points are then averaged and the average is assigned as the Lat/Long for the corresponding control point. At the end of this operation, four locations for the four control points should be accurately determined.

2.4.1.3 Generation of Infestation Map

The study area has to be grid and then sampled. The grid size is to be determined based on the size of the study area and a sample is to be taken from the middle of each grid. A reference point is to be established in the field and the relevant distances between sample locations and reference points are to be determined. This will create X and Y coordinates, in any distance unit such as meter, for each data point given that the Z axis is already determined (Z axis is infestation degree) Given X, Y, Z axis for each data point, infestation contour map then be developed using a software program like surfer.

2.4.1.4 Development of GIS Control Map

A GIS software, Like MapInfo or ArcInfo, can be utilized to convert the conventional infestation contour map into a geo-referenced GIS map. In short, this can be done by either using the digitizing or the scanning technique. Scanning involves the conversion of a hard copy of the contour up into a digital map that is then converted into a GIS map using the GPS generated control point positions. Features of the scanned maps can’t be altered, providing less control. Digitizing involves more work where the features of the contour map are tracked by the
digitizer’s puck and points along the features are registered provided that positions of
the control points are entered. Digitizing provides more control where regions of the
maps can be modified and layers can be developed for more analysis capability.

The developed GIS map can be used as a spatially-referenced database that
provides a clear illustration of the infestation problem under study. It also provides
the exact locations (Latitude and Longitude ) of the different infestation densities
within the area, which provides an easy reach to these locations using a GPS
receiver. Moreover, efficient weed control can then be implemented using GPS and
GIS based remote sensing application system.

2.4.2 Ecology of Argemone

2.4.2.1 Objectives

1. describe the Argemine habitat (soil and associated vegetation).
2. Describe the phenological stages of Argemone sp. under natural rangeland
   conditions.
3. Describe the patterns of Argemone sp. seed dispersal in natural rangeland
   conditions.
4. Describe the soil seed bank dynamics of Argemone.
5. Study the seed germination ecology of the Argemone.
6. Study the rooting patterns of Argemone.
7. Study the likely competitive and allelopathic interactions with other rangeland
   species.
8. Determine the influence of grazing methods and protection from grazing on
density and cover of Argemone sp. and associated plant species.

2.4.2.2 Study Areas

Studies will be conducted on two different Argemone-infested rangeland sites.
The two infested sites (1 km X 1 km) should reflect contrasting environments and will
be selected based mainly on differences on both Argemone sp. densities and soils.
In addition, a selected site inside the National Wildlife Research Center (NWRC ) in
Taif will be studied.
2.4.2.3 Climate, Soil and Vegetation

Climate: Winter is the rainy season in almost all regions of Saudi Arabia; however some summer rainfall also occurs in Taif (Abd El Rahman, 1986). Data on the prevailing weather will help in result interpretation of vegetation and soil moisture studies. All meteorological data will be acquired from the Meteorology and Environment Protection Agency (MEPA) and the National Commission for Wildlife Conservation and Development (NCWCD). These will include average annual precipitation and rainfall distribution, average air temperature, relative humidity, evaporation and wind speed.

Soil Studies: Eight Soil samples will be taken in each site to a depth of 30 cm for chemical and physical analysis. Analysis will include particle size distribution (Gee and Bauder, 1989), Electrical conductivity (EC) (Rhoades, 1982), soil pH (Mclean, 1982) and calcium carbonate (Nelson, 1982).

Soil Moisture: Volumetric soil water content will be monitored using Time-domain reflectometry “TDR” (Topp et al., 1984). Twenty sensors (stainless steel rods) will be randomly placed throughout each site at a depth of 15 cm. Reading of soil moisture content will be taken biweekly during the growing season over the study period.

Vegetation studies: Five transects, 100 m each within each site will be taken (Bonham, 1989). Density, frequency and cover of Arthemone sp. and associated plant species will be measured at each transect during spring season. Species composition will be determined through making a list of the different species and growth habit. Total plant density by species, absolute and relative density of plant species will be determined using 10 quadrats per transect. The shape and size of a quadrat will be decided according to the vegetation type and pattern of distribution (Bonham 1989). Frequency will be inferred from measurements of plant density. Total plant percentage cover and relative species cover will be determined according to Bonham (1989).

2.4.2.4 Autecological Studies

This phase of the project will investigate some aspects of the autecological and population biology of Arthemone. understanding the ecology of the weed will help in controlling the weed. All field experiments will involve five replicates (or transects) and five observations per replicate. All field experiments will be analyzed as a completely randomised design unless otherwise stated.
2.4.2.4.1 Phenological Study

Seedlings will be randomly selected and marked at each site in order to
describe the phenological progression of Argemone sp.. Because of the annual
nature of Argemone sp. life form and the possibility of having different phenological
stages in the field simulastanously, monitoring the phenological stages of Argemone
sp. will be initiated at the beginning of fall, winter, spring and summer seasons.
Phenological stages that will be assigned are: leaf growth, stem growth, floral buds
developing, flowering, seed development, seed ripening, seed dissemination, or dead
(West and Wein 1971). Biweekly measurements will be taken. These data along with
data from soil seed bank will be used to construct a model predicting population
dynamics of Argemone sp..

2.4.2.4.2 Rooting Patterns

In order to study the plant root development and length within soil profile, five
Argemone sp. plants at each different growth stages will be selected randomly. The
study will be carried out using a trench profile method following Farah et al. (1988). A
trench will be dug next to each plant where a grid frame will be placed to map the
root system. Total root length within the soil profile will be determined.

2.4.2.4.3 Seed Dispersal

Fully mature plants in each site will be selected to study seed dispersal of
Argemone sp.. Argemone neighboring plants within three meters radiance will be
removed in order to trace seeds to selected plants. Seed traps (Werner, 1975)
consisted of five funnels will be arranged around each plant so they would radiate in
each of the four cardinal directions (North, South, East, and West) at distances 0, 20,
40, 60, 80 cm from the plant. In total, there will be twenty seed traps next to each
plant. The number of seeds trapped in each funnel will be counted and recorded
monthly.

2.4.2.4.4 Soil Seed Bank

In this study, we will explore the seed bank dynamics in space and time though: (i)
the influence of present vegetation on a site on seed bank dynamics (ii) relationship
between seed inputs and outputs. The topsoil (50 cm X 50 cm and 10 cm deep) will
be removed and thoroughly mixed. The soil samples will be air-dried and sieved to
remove large rocks and roots. Soils will be spread into plastic germination trays (25
by 50 by 5 cm, 2 trays per a sample) and will be placed in a greenhouse and allowed
to germinate. A soil sub-sample will be watered daily. As seedlings germinate they will be identified and counted then removed from trays. Seedlings of species that could not be identified will be transplanted to pots for further identifications. The results of this experiment will estimate the current status of soil seed bank size. Another soil sub-sample will be used for screening and identification of seeds manually.

The excavated soil will be replaced with sterile sand at the beginning of fall, winter, spring and summer. During each season, any seedling emergence of *Artemisia* sp. will be recorded and sand will be excavated at the end of the season and treated as stated in the previous experiment. This experiment will examine the *Artemisia* sp. soil seed dynamics.

### 2.4.2.4.5 Seed Germination

Germination and seed viability tests will be conducted on seeds collected in fall, winter, spring and summer from plants randomly growing on natural rangeland. Germination tests will be carried out in an incubator under a series of constant temperatures (5, 10, 15, 20, 25, 30, 35°C) with alternate 12 h of light and 12 h of darkness. Germination trials will be carried out in Petri dishes lined with 0.5-cm thick absorbent cotton, which will be moistened daily with distilled water. Four replicates of 100 seed will be placed in each Petri dish. The Petri dishes will be placed randomly in the incubator for two weeks. Number of germinated seeds will be recorded at a 24-h interval and all germinated seeds will be discarded immediately. A seed is considered to have germinated when the radical length reaches <5mm. Viability test will be conducted on randomly selected seeds by soaking the seeds in 2,3,5-triphenyltetrazolium chloride for 48 h.

### 2.4.2.4.6 Competition and Allelopathic Interactions

Two experiments on competition will be conducted in all the three selected sites. A field experiment, will involve density manipulation of the most abundant four species including *Artemisia*. Plant performance (survival, growth and reproduction) will be measured. A controlled pot experiment will also be conducted using the same species in order to model species interactions according to equations of Firbank and Watkinson (1990). Density manipulation treatments will be decided upon field observation. Randomized complete block design will be used with 4 replicates.
Potential allelopathic interference of *Argemone* sp. with recruitment of valuable range plants will be assessed through a series of laboratory and field experiments (effect of aqueous extracts of different plant parts on germination, effect of plant residue on seedling emergence in the field etc.). The aim of the allelopathic experiments is to search for the least affected species in terms of seedling growth and survival in presence of *Argemone* sp. for the revegetation program. Field experiments will statistically designed as of the competition experiments while a completely randomized design will be used in laboratory experiments.

2.4.3 Integrated Weed Management

Initially, large-scale weed control should focus on range sites with an understory of residual weeds and the highest potential productivity. Suppressed weeds have the greatest chance of re-establishing dominance on these sites. These areas must be spot treated each year to ensure control and minimize re-invasion. In most cases, some percentage of the management unit will require control measures that are repeatedly applied until the weed seed bank and root reserves are exhausted.

Next, control efforts should focus on the sites adjacent to those initially treated to minimize re-introduction of the weeds. Usually, large-scale control is most effectively applied from the outside of the weed management unit inward toward its center.

Selection and application of weed control techniques in large-scale control programs depends on the specific circumstances for each portion of the management unit. Control techniques used in one area of the management unit may be inappropriate for another area. Similarly, the most effective herbicide for a particular weed species may not be labeled for use in an environmentally sensitive area.

2.4.3.1 Objectives

1) Determine the best weed control method within the IWM program.

2) Assess the effectiveness of biological program within the framework of IWM program.

3) Quantify the response of Argemone sp. to protection and animal grazing.
4) Evaluate revegetation as a suitable method to rehabilitate the Argemone sp. infested areas.

2.4.3.2 Control program

Selection of a proper control program will depend on:

1) Effectiveness of the control technique,
2) Availability of control agents or grazing animals,
3) Land use type,
4) Length of time required for control,
5) Environmental considerations and
6) Relative cost of the control techniques.

Researchers are in the process of determining if combining treatments will provide a synergistic response in controlling weeds. Some preliminary evidence suggests most control techniques are compatible.

2.4.3.3 Revegetation

Revegetation with desirable plants may be the best long-term alternative for controlling weeds on sites without an understory of desirable species. Establishing competitive grasses can minimize the re-invasion of rangeland weeds and provide excellent forage production. On appropriate sites, herbicide application after weeds have emerged, followed by plowing or disking, and drill seeding could be effective for establishing desirable species.

2.4.3.4 Effect of Protection

On the three protected sites, Argemone sp. and associated vegetation density, cover and abundance will be recorded annually for the duration of the study period using the similar methods of vegetation studies above. To compare the effect of protection, Argemone sp. and associated vegetation in three additional sites adjacent to the protected sites (but having similar habitat type) and opened for grazing will also be studied.

2.4.3.5 Grazing Studies

Adopting proper grazing management practices in conjunction with the
integrated weed management program is the third step to success. Follow-up management determines the longevity of weed control. Proper livestock grazing is essential to maintain competitive desirable plants, which will help prevent weed re-invasion after control measures are completed. A grazing plan should be developed for any management unit involved in a weed management program. The plan should include altering the season of use and stocking rates to achieve moderate grass utilization. Grazing systems should rotate livestock to allow plants to recover before being regrazed and to promote litter accumulation. Litter fall is necessary for proper nutrient cycling, which is central to maintaining a healthy plant community. Range monitoring and annual evaluations should be conducted to determine the adequacy of existing management plans.

In order to quantify the response of Argemone sp. and associated vegetation to animal utilization, four grazing paddocks will be set up each growing season in each of the two sites (total of 8 paddocks) on different Argemone sp. densities where sheep or goats or a combination of the two will graze a paddock. Paddocks locations in each site will be chosen to reflect representative invasion or density of Argemone sp.. Grazing trials will be carried out either early or late growing season. Heavy grazing is well documented to have adverse effects on both livestock performance and vegetation (Holechek et. al. 1998). Light grazing or even complete protection from grazing is seldom recognized to improve vegetation (Holechek and Stephenson 1983, Hughes 1983, Atwood and Beck 1987). Therefore, moderate grazing (20-25% utilization) will be applied. Species composition, density and aboveground phytomass will be estimated within and outside the grazing paddocks using a transect method (Bonham, 1989).

2.4.3.6 Monitoring and Evaluations

In order to determine what is happening on the range over time, monitoring is needed. Monitoring and evaluation are the keys to determining when weed and/or grazing management plans should be changed. Monitoring involves making observations, gathering data and keeping records on the range condition and trend. Monitoring must be designed to detect changes in weeds and desirable plants, biological control agents and soil surface conditions including litter accumulation, exposed soil and erosion. Management practices (e.g. grazing patterns) and factors affecting condition and trend must be monitored as well. Data from this year’s monitoring must be compared to that from earlier years, and weed and grazing management programs must be adjusted according to the predetermined management objectives.
2.4.3.7 Biological Control

Biological control practices in weed management are truly on the cutting edge of Weed Science, although this kind of weed management has been around for many years now. Here in Saudi Arabia we are looking for taking the lead in having insects introduced on *Argemone ochroleuca*. An effort will also be made to find out locally occurring insects that may feed on Argemone and help in its eradication.

The procedure for determining appropriate control agents to be introduced to Saudi Arabia to control the *A. mexicana* is quite rigorous and expensive. Potential biological control agents are identified in the home ranges of the target weed. They undergo extensive testing overseas to determine their effectiveness for controlling the target species and to determine their potential for harm to an economically or environmentally important native species. The "starvation" tests prove that the potential biological control agent will starve to death rather than feed on plant species other than the target. Failure to pass this test eliminates the insect from importation into Saudi Arabia.

After passing "starvation" tests, the potential biological agent will be imported into Saudi Arabia for further testing. If the biological agent is an insect, usually the number imported is quite small. The agent must first be multiplied into sufficient numbers for experiments to be conducted. Several crucial questions are then asked and tested. Will the insects react the same to the plant outside of its own environmental conditions? Will there be additional stress placed upon the target weed by the biological agent? Will the control agent reproduce or form important social structures in the new environment? How will the agent be dispersed? Will the agent populations survive predators in the new environment? In what specific environments is the biological agent effective? Only when these questions are answered positively, the biological control agent will be released into the environment to fill its niche as part of the system.

The time it takes from the point of release until the agent is sufficiently established to impact the target species could take years, or even decades. There are many environmental factors that influence the action of a particular biological control agent. Also, frequently, more than one control agent is required to adequately stress widespread infestations of a particular plant species. For example, in the United States, there are several control agents for spotted knapweed cleared for release. Even with that number of biological agents the range of encroachment by spotted knapweed is still increasing, but at a slower pace (Beck 1994).
From all the above, we can follow several steps for a successful biological control program using insects as the control agents.

a. Identifying target weeds

A good candidate for biological control, a weed should be:

- Non-native to the problem area.
- Present in numbers and densities greater than in its native range and numerous enough to cause environmental or economic damage.
- The weed should also be present over a broad geographic range
- Have few or no redeeming or beneficial qualities
- Have taxonomic characteristics sufficiently distinct from those of economically important and native plant species.

For classical biocontrol, the weed should occur in relatively undisturbed areas to allow for the establishment of biological control agents. Cultivation, mowing and other disturbances can have a destructive effect on many arthropod biocontrol agents. Inundative biocontrol agents such as bacteria and fungi are less sensitive to these types of disturbances so may be used in cropland.

b. Identifying control agents and assessing level of specialization

We can observe weeds in their areas of origin and collect the insects and other organisms attacking the plants and affecting their survival. These organisms are subjected to a multi-level screening process to assess their host range and their effort on the weed. These screening efforts do two things: they ensure the safety of any valuable crop, forage or native plant species that the agents may encounter when released, and they assess the efficacy of the agent.

Assessing the host range (how specific the potential biocontrol agent is to a particular plant) is probably the most important step in this process. Over very long periods, some plants and herbivores have evolved to form very close associations. Plants have developed a number of defenses, such as toxic chemicals, that plant-eating organisms (herbivores) must overcome. Some herbivores have evolved the ability to bypass only certain host plant's defenses such that they cannot feed or develop on anything else.

To find out how specialized a particular agent is, we collect and expose them to a wide assortment of plants. These plants include crops and forage species as
well as species native to the intended release area, especially if the species are close relatives of the weed. Screening potential biological control agents ensures that only those with a very narrow host range (i.e. those that represent no threat to crop, forage or native species) are released.

c. **Controlled release**

All biological control agents must be approved and reviewed before they can be released. Following the approval, the agents are released on their target weeds at selected experimental sites, which are closely monitored. Data from these sites help to assess both the agents’ potential for survival under field conditions in and their potential to cause damage to the target weed.

d. **Full sites and identifying optimal release sites**

If the agents survive our harsh climate and damage or suppress the weeds in the controlled tests, they can be released on other weed infestations. The agents are released on as many varied sites as agent numbers, time and resources will permit. Note that instructions for the proper method and timing of agent releases should be followed closely and these instructions will vary with the species of agent. The agents are then carefully monitored. Release on a large variety of sites allows scientists to find the habitats best suited to each species.

Many types of biological control agents spend at least part of their lives underground and can be very sensitive to the soil type and conditions present in the various areas. For example, the black dot leafy spurge beetle, *Aphthona nigriscutis*, spends its entire larval stage underground feeding on leafy spurge roots. Information gathered from a number of release sites indicates that these beetles prefer dry, sandy soils and will not do nearly as well in soils with higher moisture levels (Gassman 1985).

e. **Monitoring release sites (classical)**

Release sites should be monitored periodically to assess the size of the biological control agent population and the effect of the agent on the weed. A sweep net is particularly useful for sampling insect biological control agents that feed on the foliage of the weed.

Some insect biocontrol agents may need two to five years before their populations increase to a sufficient size to have a visible impact on weed numbers. When the classical control agent is establishing on a weed infestation and increasing its numbers, the site should not be mowed or disturbed. Herbicide may be used
along the boundaries of the weed infestation to help contain the weed while the biological agent is increasing in population and spread.

f. **Redistribution (classical)**

If a biological control agent is released on a site with favorable conditions, its population can grow quickly. A large number of insects can suppress the weed in this area and may allow for the establishment of an "insectary", a facility for rearing the biocontrol agent in large numbers. In these insectaries the insect population will be grown to the point where the insects can be collected in very large numbers, which then can be distributed to other weed-infested areas. Once established, the insects can suppress the weed in these areas as well.

g. **Maintaining control agent populations (classical)**

What happens to the control agents as their food supply dwindles over time? Because the weeds are never completely eradicated, a small population of insects stays on the few remaining plants. Insects that cannot be supported by the weed population at this lower level either move to new stands or die. If weed numbers increase for some reason, the number of insects will increase as well.

### 2.5 UTILIZATION

Defiantly, most of the stated objectives will be attained. Results will delineate areas infested with Argemone and possible advancement of this weed. They will also yield valuable information on various ecological aspects of Argemone, synthesize an integrated weed management plan for this plant and explore both harmful and beneficial chemical components. Careful interpretation of results will help in formulating a management plan for the infested areas and provide information for possibility of giving some recommendations to either go further to investigate this plant or not. In addition, it will open the door for other similar problems to be studied in the same or more appropriate ways.

### 2.6 MANAGEMENT PLAN

The studies will be approached from the respective of teamwork. However, in order to accomplish the stated objective, the responsibility of climate, soil, and vegetation studies in addition to autecological studies, and effect of protection and control grazing on vegetation will be assigned to specialists in these areas.
Dr. Abdulaziz M. Assaeed

A professor of range ecology at the College of Food and Agricultural Sciences, King Saud University will be the principal investigator. He graduated from the University of Nottingham, UK. His current interests are in range plant ecology (including seed germination, seedling establishment, plant competition, allelopathy, and range plant species diversity). He authored and co-authored several scientific papers in range ecology and forage production. In particular, he worked on Rhazya stricta, a noxious range weed plant native to Saudi Arabia. He translated a text-book in range management for which he received an award from the “Kuwait Foundation for the Advancement of Sciences” as the best translated scientific arabic book in 2002. He supervised seven graduate students (PhD and MSc.) in the field of range ecology, range management and biodiversity and participated in thesis examining committees of several others locally and abroad. Being the principle investigator, he will be in charge of the project administration and communication with KACST. He will mainly be in charge of argemone ecological studies (phonological studies, soil seed-bank, competition and allelopathy) but will also participate in grazing studies. He will also participate in data analysis and report writing.

Dr Turki Ali Al-Turki

Research professor, Natural Resources and Environmental Research Institute, King Abdulaziz City for Science and Technology (KACST), is the founder of KACST herbarium and holds charge of that. He graduated from the school of Biological Sciences, University of East Anglia, UK in 1992. He has traveled all over the Kingdom of Saudi Arabia for the cause of plant collecting as an enthusiastic plant hunter. Al-Turki is biosystematic and germination ecology expertise. In addition to his expertise of the flora of the Kingdom of Saudi Arabia, he has experimented with a large number of seed samples for study of their germination potential and cytological investigations, along with characterization for long term preservation in the plant sciences laboratory which he takes care of. He has attended several conferences in both Eastern and Western countries, especially concerning seed germination ecology and gene-banking in which he obtained training at the prestigious National Seed Storage Laboratory, Fort Collins, USA. Al-Turki is also a member of many cross-institutional committees that will benefit the project immensely.

Al-Turki, due to his expertise in plant morphology and ecology, will be responsible for field explorations of Argemone and prepare herbarium specimens, in addition to study of seed characterization and germination potentials of this
hazardous weed. He will also offer his assistance to the principal investigator in the administration of the project and the preparation of technical reports. Al-Turki will be visiting various national and international herbaria to evaluate the specimens lodged in them for the study of variation patterns and possible hybridization in this genus.

**Dr. Khalid Al-Mutlaq**

Dr Al-Mutlaq is an Associate Professor at the College of Food and Agricultural Sciences, King Saud University. He obtained his Ph. D. from Oregon State University in the year 1999. Dr Al-Mutlaq will be responsible for preparing and providing project’s requirements from time to time and will study Argemone infestation and its control by studying herbicides effect on different populations and on the associate rangeland plant species such as grasses etc. He will be responsible for biocontrol studies. He will be in charge of Argemone control studies. He will participate in data collection analysis and report writing.

**Dr. Saud L. Al-Rowaily:**

Assistant professor of range management and rehabilitation at the College of Food and Agricultural Sciences, King Saud University, obtained his Ph.D. from Utah State University, USA by researching on leafy spurge (*Euhorbia esula* L.) a noxious weed infesting rangelands of the Northern Great Plains of the USA and Canada. His interests are rangeland rehabilitation and grazing management. He supervised MSc students in the field of range ecology, range management and biodiversity and participated in thesis examining committees of others. He will be in charge of weed inventory and all grazing revegetation studies, but will participate in conducting the ecological studies (seed dispersal, rotting pattern and seed germination). Further he will participate in data analysis and report writing.

**Mr. AbdelRahman Al-Daud**

Mr Al-Daud is a staff member of the ministry of Agriculture, Riyadh. Currently, he is the deputy director of the Rangeland and Forest Service. He obtained his Bachelor’s degree from the college of Agriculture, King Saud University in the year 1976. Mr Al-Daud has attended several training courses in the USA in the field of range management. He also participated in several research projects including the currently on-going project of range and forest survey conducted by the Ministry of Agriculture. He will be assisting the principal Investigator in the field studies of the two species of Argemone growing in Taif region. Mr. Al-Daud will be collecting data on the ecology, growth forms and associates of Argemone that grow in the same area.
2.7 WORK PLAN

The team of investigators will be involved in all or some stages for three years. During this period, a guard and one technician will be working at the rate of 15 hrs/week and 20 hrs/week respectively.

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<th>Activity</th>
<th>Year 1</th>
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<th>Year 3</th>
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<tr>
<td>Field and herberia Argemone specimens study in the field</td>
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<td>Purchase of materials &amp; equipment</td>
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<td>Site setup studies sites &amp; fencing</td>
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<td>Argemone control</td>
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<td>Seed collection &amp; Lab Studies</td>
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<td>Soil seed bank studies</td>
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<td>Survey, monitoring and map development</td>
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<td>Phenological studies</td>
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BUDGET

3.1 Senior Investigators:
Senior investigators will work for three years and will receive SR 2000 per month during the non-vacation period. Mr. Al-Daud will receive SR 1000 per month. The principle investigator will work for 11 months in the first year during summer. Allowances for Investigators during the the project duration will be as follows:

Table 1 Honoria for the senior investigators

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<thead>
<tr>
<th>No.</th>
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<th>1st year</th>
<th>2nd year</th>
<th>3rd year</th>
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<td>2</td>
<td>Dr. Turki Al-Turki* (C-O)</td>
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<td>Dr. Khalid F. Al-Mutlaq (C-O)</td>
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<td>5</td>
<td>Mr. A. N. Al-Daud (C-O)</td>
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* Dr T. A. Al-Turki is a staff member of the KACST and is not entitled to the honorarium

3.2 Other Personnel:

I. Research Assistant - One full-time research assistant will be employed to assist senior investigators during the course of the project. He will work for 6 months in the first and the last year and will receive a salary of SR 4,000 per month and a housing allowance equivalent to 3-month salary per year.

II. Technical Assistant - One part-time field technical assistant will be nominated by the Ministry of Agriculture. He will receive SR 1,000 per month for 24 months starting from the second half of the first year.

III. Laboratory Technicians - Two full-time laboratory technicians will be recruited. They will receive SR 1,600 per month. They will work for 24 months starting from the second half of the first year.

IV. Secretary - A part-time secretary will be hired during the three years of the project duration. He will receive SR 6,000 per year.

V. Guard - Since most of the studies will involve field work in open rangelands, a local guard will be employed during the course of the project. He will start at the beginning of the fourth month of the first year and will receive SR 1000 per month for 30 months starting from the 3rd. month of the first year. Detailed budget for the junior staff and guard will be as follows:
Table 2. Allowance for other research personnel and guard

<table>
<thead>
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<th>No.</th>
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<th>2nd.</th>
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<td>+ 3-month housing allowance + tickets</td>
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<td>3</td>
<td>Full-time Laboratory Technicians (2) (for 24 months)</td>
<td></td>
<td>19,200</td>
<td>38,400</td>
<td>19,200</td>
<td>76,800</td>
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<tr>
<td></td>
<td>SR 1,600 / month</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>4</td>
<td>Secretary</td>
<td></td>
<td>6,000</td>
<td>6,000</td>
<td>6,000</td>
<td>18,000</td>
</tr>
<tr>
<td>5</td>
<td>Full-time Guard (1) (for 30 months)</td>
<td></td>
<td>9,000</td>
<td>12,000</td>
<td>9,000</td>
<td>30,000</td>
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<tr>
<td></td>
<td>SR 1,000 / month</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>71,200</td>
<td>122,400</td>
<td>70,200</td>
<td>263,800</td>
</tr>
</tbody>
</table>

3. 3 Equipments, Material and Supplies:
The project involves both field and laboratory studies that require basic materials, and equipments and supplies. Fortunately, the Ministry of Agriculture will participate in funding the project especially in fencing, local transportation and machinery required for revegetating the degraded rangelands and herbicide application. The next two tables contains the required equipments.

Table 3. Fund allocation for field and laboratory equipments, material and facilities requested from KACST

<table>
<thead>
<tr>
<th>Equipments</th>
<th>1st year</th>
<th>2nd year</th>
<th>3rd year</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 GPS Receiver</td>
<td>10,000</td>
<td></td>
<td></td>
<td>10,000</td>
</tr>
<tr>
<td>Time-domain Reflectometer and Probes</td>
<td>15,000</td>
<td></td>
<td></td>
<td>15,000</td>
</tr>
<tr>
<td>1 Growth Chamber</td>
<td>20,000</td>
<td></td>
<td></td>
<td>20,000</td>
</tr>
<tr>
<td>Sub-total</td>
<td>45,000</td>
<td></td>
<td></td>
<td>45,000</td>
</tr>
<tr>
<td>Materials</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planting Pots, Media and Seeds</td>
<td></td>
<td>1,000</td>
<td></td>
<td>1,000</td>
</tr>
<tr>
<td>Plastic Germination Trays</td>
<td></td>
<td>1,000</td>
<td></td>
<td>1,000</td>
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<tr>
<td>Funnel Seed Traps</td>
<td></td>
<td>1,000</td>
<td></td>
<td>1,000</td>
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<tr>
<td>Sweep Nets</td>
<td>1,000</td>
<td></td>
<td></td>
<td>1,000</td>
</tr>
<tr>
<td>Insects, Insect diet, Collection Boxes and Specimen Cabinets</td>
<td>5,000</td>
<td>5,000</td>
<td></td>
<td>10,000</td>
</tr>
<tr>
<td>Herbicides</td>
<td>5,000</td>
<td>5,000</td>
<td></td>
<td>10,000</td>
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<tr>
<td>Animals</td>
<td>15,000</td>
<td></td>
<td></td>
<td>15,000</td>
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<tr>
<td>Animal feed</td>
<td>11,600</td>
<td>15,800</td>
<td>11,600</td>
<td>39,000</td>
</tr>
<tr>
<td>Sub-total</td>
<td>37,600</td>
<td>28,800</td>
<td>11,600</td>
<td>78,000</td>
</tr>
<tr>
<td>Facilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Tech Controlled Glass House with Partitions</td>
<td>80,000</td>
<td></td>
<td></td>
<td>80,000</td>
</tr>
<tr>
<td>Total</td>
<td>162,600</td>
<td>28,800</td>
<td>11,600</td>
<td>203,000</td>
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Table 4. Contribution provided towards the project by the Ministry of Agriculture
(All financial contributions will be managed separately by the Ministry)

<table>
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<th>3rd year</th>
<th>Total</th>
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<tr>
<td>Fencing (SR 50 / 1m length)</td>
<td>220,000</td>
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<td>--------</td>
<td>220,000</td>
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<td>Equipments for reseeding and</td>
<td>30,000</td>
<td>15,000</td>
<td>5,000</td>
<td>50,000</td>
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<tr>
<td>mechanical and chemical weed</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local transportation (vehicle +</td>
<td>130,000</td>
<td>2,500</td>
<td>2,500</td>
<td>135,000</td>
</tr>
<tr>
<td>fuel)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>380,000</strong></td>
<td><strong>17,500</strong></td>
<td><strong>7,500</strong></td>
<td><strong>405,000</strong></td>
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</table>

3.4 Travel Allowance
The project involves considerable field work and travel to follow up field experiments.
A four wheel vehicle, a driver and fuel will supplied by the Ministry of Agriculture. Local economy class air tickets costing SR 550 are required for all personnel except for one field technician who resides in Taif area. Dr. Assaeed and Dr. Al-Turki are entitled for SR 600 daily allowance. Dr. Al-Mutlaq and Dr. Al-Rowaily are entitled for SR 525 daily allowance. Mr. Al-Daud is entitled for SR500 while other personnel are entitled for SR 200 daily. The following table explains the travel allowance required for investigators.

Table 5. Travel allowance for the project team.

<table>
<thead>
<tr>
<th>Name</th>
<th>No. of days/ year</th>
<th>Year</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prof. A. M. Assaeed (P-I) Tickets</td>
<td>(7)+(4+4)+(6)</td>
<td>4,200</td>
<td>4,800</td>
</tr>
<tr>
<td></td>
<td>550</td>
<td>1,100</td>
<td>550</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,800</td>
<td>550</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12,600</td>
<td>2,200</td>
</tr>
<tr>
<td>Prof. Turki Al-Turki* (Co-I) Tickets</td>
<td>7+7</td>
<td>4,200</td>
<td>4,200</td>
</tr>
<tr>
<td></td>
<td>550</td>
<td>550</td>
<td>1,100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8,400</td>
<td>1,100</td>
</tr>
<tr>
<td>Dr. Khalid F. Al-Mutlaq (Co-I) Tickets</td>
<td>(6+5+5)+(6+6+7)+(6+5+5)</td>
<td>8,400</td>
<td>9,975</td>
</tr>
<tr>
<td></td>
<td>1,650</td>
<td>1,650</td>
<td>1,650</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8,400</td>
<td>1,650</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26,775</td>
<td>4,950</td>
</tr>
<tr>
<td>Dr. Saud L. Al-Rowaily (Co-I) Tickets</td>
<td>(6+5+5)+(7+5+7)+(5+6+6)</td>
<td>8,400</td>
<td>10,500</td>
</tr>
<tr>
<td></td>
<td>1,650</td>
<td>1,650</td>
<td>1,650</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8,925</td>
<td>1,650</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27,825</td>
<td>4,950</td>
</tr>
<tr>
<td>Mr. A. N. Al-Daud (C-O) Tickets</td>
<td>(5+5+5)+(6+5+3)+(3+3+3)</td>
<td>7,500</td>
<td>8,000</td>
</tr>
<tr>
<td></td>
<td>1,650</td>
<td>1,650</td>
<td>1,650</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4,500</td>
<td>1,650</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4,950</td>
<td>1,650</td>
</tr>
<tr>
<td>Lab. Technicians</td>
<td>2× [(7+8)+(7+8)+(7+7)]</td>
<td>6,000</td>
<td>6,000</td>
</tr>
<tr>
<td></td>
<td>2,200</td>
<td>2,200</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>17,600</td>
<td>6,600</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>46,950</strong></td>
<td><strong>52,275</strong></td>
<td><strong>38,725</strong></td>
</tr>
</tbody>
</table>

3.5 Total Budget
For the accomplishment of the results as outlined in the project proposal, a total sum of SR 872750 will be needed as summarised below. A further sum of SR 405,000 will be provided by the Ministry of Agriculture for the completion of the project.
Table 6. Budget Summary for the duration period of project

<table>
<thead>
<tr>
<th>Budget Head</th>
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<th>2nd year</th>
<th>3rd year</th>
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<tr>
<td>Honoraria for Investigators</td>
<td>64,000</td>
<td>72,000</td>
<td>72,000</td>
<td>208,000</td>
</tr>
<tr>
<td>Honoria for other research personnel</td>
<td>71,200</td>
<td>122,400</td>
<td>70,200</td>
<td>263,800</td>
</tr>
<tr>
<td>Equipments, Materials and Facilities</td>
<td>162,600</td>
<td>28,800</td>
<td>11,600</td>
<td>203,000</td>
</tr>
<tr>
<td>Details in table 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travel within country (allowances and tickets)</td>
<td>46,950</td>
<td>52,275</td>
<td>54,725</td>
<td>153,950</td>
</tr>
<tr>
<td>Consultant</td>
<td>3,000</td>
<td>9,000</td>
<td>3,000</td>
<td>15,000</td>
</tr>
<tr>
<td>Stationary &amp; Reports</td>
<td>---------</td>
<td>---------</td>
<td>6,000</td>
<td>6,000</td>
</tr>
<tr>
<td>Total</td>
<td>347,750</td>
<td>284,475</td>
<td>216,525</td>
<td>849,750</td>
</tr>
</tbody>
</table>

Table 7. Contribution by the Ministry of Agriculture towards the project

<table>
<thead>
<tr>
<th></th>
<th>1st year</th>
<th>2nd year</th>
<th>3rd year</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>380,000</td>
<td>17,500</td>
<td>7,500</td>
<td>405,000</td>
</tr>
</tbody>
</table>

Total Grant Requested: SR 849,750
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<th>الدعم المطلوب</th>
</tr>
</thead>
<tbody>
<tr>
<td>رئيس البحث: د. عبد العزيز بن محمد السعید</td>
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</tr>
<tr>
<td>مشارك (1): د. تركي بن علي التركي</td>
<td></td>
</tr>
<tr>
<td>مشارك (2): د. خالد بن فرج المطلق</td>
<td></td>
</tr>
<tr>
<td>مشارك (3): د. سعود بن نبيل الرويلي</td>
<td></td>
</tr>
<tr>
<td>مشارك (4): د. عبد الرحمن بن ناصر الداوود</td>
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<tr>
<td>مجموع البند (1)</td>
<td>64000</td>
</tr>
<tr>
<td>مساعد بحث عدد ١</td>
<td>٣١٠٠</td>
</tr>
<tr>
<td>طالب جامعہ</td>
<td>١٩٢٠</td>
</tr>
<tr>
<td>إداريون</td>
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<tr>
<td>مهندسین آخرون</td>
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<td>مهارات أخرى</td>
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<td>مجموع البند (2)</td>
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<td>المواد</td>
<td>٣٧٠٠</td>
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<tr>
<td>التجهيزات</td>
<td>٨٠٠٠</td>
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<tr>
<td>مجموع البند (3)</td>
<td>١٦٢٢٠٠</td>
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<td>الرحلات</td>
<td>٤٦٩٥</td>
</tr>
<tr>
<td>المؤتمرات</td>
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</tr>
<tr>
<td>مجموع البند (4)</td>
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المشرف على الادارة العامة لبرامج المنح البحثیة:

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<th>التوقيع</th>
<th>التاريخ</th>
</tr>
</thead>
</table>

gdrgrp@kacst.edu.sa

P.O. Box : 6086 , Riyadh 11442 Tel : 01 4813354 , Fax :01 4813878/01 4813837 E-mail: gdrgrp@kacst.edu.sa
الميزانية المحدودة

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<th>الاستعمال الرسمي</th>
<th>الدعم المطلوب</th>
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<td>إداريون</td>
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<td>مهارات أخرى عدد 2 ( الفني حقل)</td>
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<td>التجهيزات</td>
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الإدارة العامة لبرامج المناهج البحثية
للمملكة العربية السعودية
مؤسسة الملك عبد العزيز للعلوم والتقنية
مدينه واد مأرب، اليمن
السعودية
الجهة: جامعة الملك سعود
الтика:自由贸易区
المدة: ثلاث سنوات
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<td>20000</td>
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<td>التجهيزات</td>
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<td>مجموع البند (3)</td>
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<thead>
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المشرف على الإدارة العامة لبرامج المنح البحثية

المبحث الرئيسي

المادة المفوضة

الاسم

التوقيع

التاريخ

sa.edu.kacst@gdrgp
P.O. Box: 6086, Riyadh 11442
Tel : 01 4813354, Fax: 01 4813878/01 4813837
E-mail: gdrgp@kacst.edu.sa

ص. ب. 10-6-8- الرياض 1442 هـ 1481383878/01 1481383878/01 1454334424
P.O. Box: 6086, Riyadh 11442 Tel : 01 4813354, Fax :01 4813878/01 4813837
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الباحث الرئيس: كبير، المهندس علي العليان
المشرف على الادارة العامة لبرامج المحمل البحثية: الدكتور موضوع

المملكة العربية السعودية
渑هنلة الملك عبد العزيز
المؤسسة العامة للعلوم والتقنية
إدارة العامة لبرامج المحمل البحثية

gdrp@kacst.edu.sa

ص. ب. 2086 - الرياض 1444 (1488) - 1489/118/10 - 1489/118/10
P.O. Box: 6086, Riyadh 11442 Tel: 01 4813354, Fax: 01 4813878/01 4813837 E-mail: gdrp@kacst.edu.sa
King Abdulaziz City for Science and Technology

General Directorate of Research Grants Programs

Curriculum Vitae Form

<table>
<thead>
<tr>
<th>Name (English)</th>
<th>Abdulaziz Mohammad Sulaiman Assaeed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name (Arabic)</td>
<td>عبدالعزيز محمد سليمان السعدي</td>
</tr>
</tbody>
</table>

Mailing Address
- P.O. Box 2460: City Riyadh: Zip Code: 11451
- Country: Saudi Arabia
- Telephone No. (Home): 1+2307595
- Telephone No. (Office): 1+4678343
- Mobile No.: 0505277274
- Fax No.: 1+4678467
- E-Mail: assaeed@ksu.edu.sa

Institute / University (Work): King Saud University
College: Food & Agric Sc. Department: Plant Production

Nationality: ☑ Saudi Arabia □ Other (Specify):
Date of Birth: 01/04/1954 Country of Birth: Saudi Arabia

Languages: ☑ Arabic ☑ English □ Other (Specify)

Highest Degree: Ph.D Degree Date: 01/04/1989
University: Nottingham Country United Kingdom
Academic Title: ☑ Professor □ Associate Prof □ Assistant Prof □ Lecturer □ Others:
Job Title (If Any): Head, Plant Production Dept.

Field: ☑ Medicine ☑ Engineering ☑ Basic Science ☑ Agriculture ☑ Human Sciences □ Others:
Sub-Field (From List): Range Science

Majors: Range Ecology

Current Specialization & Research Interests: Autecology and synecology of range plants, invasive weeds in rangelands, range plant diversity, rangeland restoration.

* Please attach the PHD & MS thesis titles & list of your publications.
Abdulaziz M. Assaeed, CV. Continuation Sheet


# نموذج السيرة الذاتية

<table>
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<tr>
<th>الاسم (العربي)</th>
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<td>Name (English)</td>
<td>Saud L. R. Al-Rowaily</td>
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**عناوين المرة: 42/1-2932/2023**

**المملكة العربية السعودية**

**مدينة الملك عبد العزيز للعلوم والتكنولوجيا**

**الإدارة العامة لبرامج المح الحالية**

## المهارات العلمية

**لغة: العربية**

- علم الأحياء
- علم البيئة
- علوم الأنسجة
- جيولوجيا
- طب نباتي

**لغة: الإنجليزية**

- علوم الحيوان
- علوم الحشرات
- علوم الأحياء

## الإهتمامات البحثية المتميزة

- بيئة المكبس (الصحراوية)
- تنمية وتحسين الموارد
- نظام وإدارة الرعي

## الملاحظات

- **الرغم إزالة صفحة رسالة الدكتوراه والدكتوراه والأعمال للنشرة**

## الرسالة

**التخصص: علم الزراعة**

**المجالات المنهجية:**

- إدارة
- إنتاج
- نشر
- نموذجات الأكل

**المجالات التطبيقية:**

- حشرة
- نبات
- مياه

## العنوان المقالة

**عنوان المقالة:**

**الموضوع:**

**الدكتور:**

**المملكة العربية السعودية**

**مدينة الملك عبد العزيز للعلوم والتكنولوجيا**

**الإدارة العامة لبرامج المح الحالية**

**الاسم:**

**العنوان:**

**المجالات المنهجية:**

- إدارة
- إنتاج
- نشر
- نموذجات الأكل

**المجالات التطبيقية:**

- حشرة
- نبات
- مياه
# Curriculum Vitae Form

**Name (English):** Saud L. R. Al-Rowaily  
**Name (Arabic):**  

**Mailing Address:**  
P.O. Box 2460: City Riyadh : Zip Code: 11451  
Country : Saudi Arabia  
Telephone No. (Home) : 4678455  
Mobile No. : 0503462093  
Fax No. : 4678467  
E-Mail : srowaily@ksu.edu.sa  

**Institute / University (Work):** King Saud Univ.  
**College:** Food and Agric Sciences  
**Department:** Plant Production  

**Nationality:** ☑ Saudi Arabia  
**Other (Specify):**  

**Date of Birth:** 19/9/1385  
**Country of Birth:** Saudi Arabia  

**Languages:** ☑ Arabic  ☑ English  
**Other (Specify):**  

**Highest Degree:** Ph.D  
**Degree Date:** 10/10/1996  
**University:** Utah State University  
**Country:** USA  

**Academic Title:** ☑ Professor  ☑ Associate Prof  ☑ Assistant Prof  ☑ Lecturer  ☑ Others :  
**Job Title (If Any):**  

**Field:** ☑ Medicine  ☑ Engineering  ☑ Basic Science  ☑ Agriculture  ☑ Human Sciences  ☑ Others :  
**Sub-Field (From List):** Range management  
**Majors:** Range Science  

**Current Specialization & Research Interests:**  

* Please attach the PHD & MS thesis titles & list of your publications.


4- الرويلي، سعود، (١٠٠٠٢م). تأثير التخزين والمجدش على انبات ثلاثة شجيرات محلية من شمال المملكة العربية السعودية. الدراسات التقنية لليبراء العلمي مجلد ٢٢(٤) ص ٤٢٣-٤٣٠


6- الرويلي، سعود، (٢٠٠٣م). الوضع الراهن للمراعي في المملكة العربية السعودية: مراحل التدهور والمداخلات الادارية. مجلة الخليج العربي للبحوث العلمية مجلد (٣١) عدد (٣) ١٨٨-١٩٦


8- الرويلي، سعود، ولها، (٤٤٤م). مراحل النمو والقيمة الغذائية لنبات العرفة في موقع روعي بالمنطقة الشمالية من المملكة العربية السعودية. الجديد في البحوث الزراعية مجلد (٩) عدد (٣) ٥٥١-٥٦١

اللقاءات العلمية

أولا: المؤتمرات (محكمة)


Abstracts


الرويلي، سعود بن ليلى (١٤٢٤هـ). مفهوم الحمولة الرعوية ومدى ملاءمتها لرعاي المملكة العربية السعودية - وجهة نظر. اللقاء العلمي السنوي الثاني والعشرون، الجمعية السعودية لعلوم الحياة، القصيم 27-28 شوال ١٤٢٤هـ. صفحة ٩٠.

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**King Abdulaziz City for Science and Technology**

**General Directorate of Research Grants Programs**

Kingdom of Saudi Arabia
Khlid F. Al-Mutlaq
Chemical control of weeds
Weed Biology
- Chemical control of weeds

Khlid F. Al-Mutlaq
Chemical control of weeds
Weed Biology
- Chemical control of weeds

King Abdulaziz City for
Science and Technology

General Directorate of Research Grants

Kingdom of Saudi Arabia

Name (English) : Khlid F. Al-Mutlaq
Name (Arabic) :

Mailing Address
P.O. Box 2460: City Riyadh : Zip Code: 11451
Country : Saudi Arabia
Telephone No. (Home) :
Telephone No. (Office): 4678867
Mobile No. :
Fax No. : 4678423
E-Mail :

Institute / University (Work) : King Saud Univ.
College : Food and Agric Sciences Department : Plant Protection

Nationality : ☑ Saudi Arabia ☐ Other (Specify) :
Date of Birth : 24/9/1968 Country of Birth : Saudi Arabia

Languages : ☑ Arabic ☑ English ☐ Other (Specify)

Highest Degree : Ph.D Degree Date : //1999
University : Oregon State University Country USA
Academic Title : ☑ Professor ☑ Associate Prof ☐ Assistant Prof ☑ Lecturer ☐ Others :
Job Title (If Any) :

Field : ☑ Medicine ☑ Engineering ☑ Basic Science ☑ Agriculture ☑ Human Sciences ☐ Others :
Sub-Field (From List) : Pesticides

 Majors : Weed Control

Current Specialization & Research Interests:

- Weed Biology
- Chemical control of weeds

* Please attach the PHD & MS thesis titles & list of your publications.
Khalid F. Al-Mutlaq CV. Continuation Sheet


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**عووان المراسلة:**

- **الجهة:** وزارة الزراعة و التغذية
- **القسم:** إدارة الزراعة والغابات

**اللغات:** العربية، الإنجليزية

- **المستوى:** الثانوي
- **المستوى العلمي:** البكالوريوس
- **المستوى الجامعي:** جامعة الملك سعود

**التعليم الأساسي:**

- **اللغة:** عربية
- **الرياضيات:** عربية
- **الجغرافيا:** عربية
- **الفيزياء:** عربية
- **اللغة الثانية:** عربية

**الاهتمامات البحثية الحالية:**

- **البحث:** دفاع عن الإنتاج الزراعي، تطوير النطاق، وتخطيط الأراضي
- **البحث:** تطوير الفنون المعمارية، البحث في الفنون، والبحث في الفنون

**البريد الإلكتروني:** forest@agriwat.gov.sa
King Abdulaziz City for Science and Technology

General Directorate of Research Grants Programs

( DB/CV-1/24)

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Name (Arabic) : عبد الرحمن ناصر الداوود

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Telephone No. (Office): 4033702
Mobile No. : 0504440733
Fax No. : 4033702
E-Mail : analdawood@agrwat.gov.sa

Institute / University (Work) : Ministry of Agriculture
College : Department : Rangeland and Forest Management

Nationality : ☑ Saudi Arabia ☐ Other (Specify) :
Date of Birth : Country of Birth : Saudi Arabia

Languages : ☑ Arabic ☑ English ☐ Other (Specify)

Highest Degree : Bsc. Degree Date : 1976
University : King Saud University Country Saudi Arabia
Academic Title : ☐ Professor ☐ Associate Prof ☐ Assistant Prof ☐ Lecturer ☑ Others : Agric. Researcher

Job Title (If Any) : Director of Rangeland Management

Field : ☑ Medicine ☑ Engineering ☑ Basic Science ☑ Agriculture ☑ Human Sciences ☐ Others :
Sub-Field (From List) : Range management
Majors : Range Science

Current Specialization & Research Interests:

* Please attach the PHD & MS thesis titles & list of your publications.

Kingdom of Saudi Arabia

* Please attach the PHD & MS thesis titles & list of your publications.