EFFECT OF WATER QUALITY AND WEEDING ON THE GROWTH, YIELD, QUALITY AND SEED PRODUCTION OF THREE ALFALFA (Medicago sativa L.) CULTIVARS

By
Bakri Mohamed Elhassan Osman
B.Sc. (Agric.) U. of K., 1991

A Thesis Submitted to the University of Khartoum in Fulfillment of the Requirements for the Ph.D. Degree in Agriculture (Agronomy)

Supervisor: Dr. Awad Osman Mohamed Abu Suwar

Department of Agronomy
Faculty of Agriculture
University of Khartoum
November 2008
DEDICATION

To:

The soul of my late brother, the martyr, Omer Abdelaziz,
My late parents
My wife (Amal) and my kid (Hiba).
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td>i</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>ARABIC ABSTRACT</td>
<td>iv</td>
</tr>
<tr>
<td>CHAPTER ONE: INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>CHAPTER TWO: LITERATURE REVIEW</td>
<td>4</td>
</tr>
<tr>
<td>2.1 Crop requirements and establishment</td>
<td>4</td>
</tr>
<tr>
<td>2.2 Inoculation</td>
<td>6</td>
</tr>
<tr>
<td>2.3 Varieties</td>
<td>6</td>
</tr>
<tr>
<td>2.4 Fertilizer requirements</td>
<td>8</td>
</tr>
<tr>
<td>2.5 Irrigation</td>
<td>8</td>
</tr>
<tr>
<td>2.6 Weeding</td>
<td>9</td>
</tr>
<tr>
<td>2.7 Seed production</td>
<td>10</td>
</tr>
<tr>
<td>2.8 Forage harvest</td>
<td>11</td>
</tr>
<tr>
<td>2.9 Forage yield</td>
<td>13</td>
</tr>
<tr>
<td>CHAPTER THREE: MATERIALS AND METHODS</td>
<td>14</td>
</tr>
<tr>
<td>3.1 Site description</td>
<td>14</td>
</tr>
<tr>
<td>3.1.1 Location and climate</td>
<td>14</td>
</tr>
<tr>
<td>3.1.2 Land preparation</td>
<td>14</td>
</tr>
<tr>
<td>3.1.3 Treatments and design</td>
<td>14</td>
</tr>
<tr>
<td>3.2 Cultural practices</td>
<td>15</td>
</tr>
<tr>
<td>3.2.1 The seeds</td>
<td>15</td>
</tr>
<tr>
<td>3.2.2 Weeding</td>
<td>15</td>
</tr>
</tbody>
</table>
3.3 Parameters

3.3.1 Nodulation

3.3.1.1 Number of nodules per plant

3.3.1.2 Nodule fresh and dry weights

3.3.1.3 Nodule effectiveness

3.3.2 Growth attributes

3.3.2.1 Plant density

3.3.2.2 Plant height (cm)

3.3.2.3 Leaf area index (LAI)

3.3.2.4 Leaf to stem ratio

3.3.2.5 Shoot/root ratio

3.3.3 Forage yield

3.3.3.1 Fresh yield

3.3.3.2 Dry yield

3.3.4 Seed yield

3.3.4.1 Number of racemes per plant

3.3.4.2 Number of pods per raceme

3.3.4.3 Number of seeds per pod

3.3.4.4 Thousand seed weight

3.3.4.5 Seed yield per plant

3.3.4.6 Total seed yield

3.3.5 Proximate analysis

3.3.5.1 Crude protein and crude fiber

3.3.6 Number of weeds per unit area
3.3.7 Data analysis

**CHAPTER FOUR: RESULTS**

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>21</td>
</tr>
<tr>
<td>4.1.1</td>
<td>21</td>
</tr>
<tr>
<td>4.1.2</td>
<td>21</td>
</tr>
<tr>
<td>4.1.3</td>
<td>21</td>
</tr>
<tr>
<td>4.1.4</td>
<td>21</td>
</tr>
<tr>
<td>4.2</td>
<td>26</td>
</tr>
<tr>
<td>4.2.1</td>
<td>26</td>
</tr>
<tr>
<td>4.2.2</td>
<td>26</td>
</tr>
<tr>
<td>4.2.3</td>
<td>32</td>
</tr>
<tr>
<td>4.2.4</td>
<td>32</td>
</tr>
<tr>
<td>4.2.5</td>
<td>39</td>
</tr>
<tr>
<td>4.3</td>
<td>39</td>
</tr>
<tr>
<td>4.3.1</td>
<td>39</td>
</tr>
<tr>
<td>4.4</td>
<td>50</td>
</tr>
<tr>
<td>4.4.1</td>
<td>50</td>
</tr>
<tr>
<td>4.4.2</td>
<td>50</td>
</tr>
<tr>
<td>4.4.3</td>
<td>54</td>
</tr>
<tr>
<td>4.4.4</td>
<td>54</td>
</tr>
<tr>
<td>4.4.5</td>
<td>54</td>
</tr>
<tr>
<td>4.5</td>
<td>58</td>
</tr>
</tbody>
</table>
4.5.1 Crude protein 58
4.5.2 Crude fiber 58
4.6 Weed measurement 58

CHAPTER FIVE: DISCUSSION 62
5.1 Nodulation 62
5.2 Vegetative growth 62
5.3 Forage yield 63
5.4 Seed production 65
5.5 Nutritive value 66
5.6 Weed measurements 66

SUMMARY AND RECOMMENDATIONS 67
REFERENCES 69
APPENDIX 78
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Effect of water quality and weeding on number of nodules of alfalfa cultivars</td>
<td>22</td>
</tr>
<tr>
<td>2</td>
<td>Effect of water quality and weeding on nodule fresh weight of alfalfa cultivars</td>
<td>23</td>
</tr>
<tr>
<td>3</td>
<td>Effect of water quality and weeding on nodule dry weight of alfalfa cultivars</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>Effect of water quality and weeding on number of effective nodules of alfalfa cultivars</td>
<td>25</td>
</tr>
<tr>
<td>5</td>
<td>Plant density of alfalfa (plants/m²) as affected by cultivars</td>
<td>27</td>
</tr>
<tr>
<td>6</td>
<td>Effect of water treatments on plant density (plants/m²) of alfalfa cultivars</td>
<td>28</td>
</tr>
<tr>
<td>7</td>
<td>Effect of weeding on plant density (plants/m²) of alfalfa cultivars</td>
<td>29</td>
</tr>
<tr>
<td>8</td>
<td>Plant height of alfalfa (cm) as affected by cultivars</td>
<td>30</td>
</tr>
<tr>
<td>9</td>
<td>Effect of water treatments on plant height (cm) of alfalfa cultivars</td>
<td>31</td>
</tr>
<tr>
<td>10</td>
<td>Effect of weeding on plant height (cm) of alfalfa cultivars</td>
<td>33</td>
</tr>
<tr>
<td>11</td>
<td>Shoot/root ratio as affected by alfalfa cultivars</td>
<td>34</td>
</tr>
<tr>
<td>12</td>
<td>Effect of water treatment on shoot/root ratio of alfalfa of cultivars</td>
<td>35</td>
</tr>
<tr>
<td>13</td>
<td>Effect of weeding on shoot/root ratio of alfalfa cultivars</td>
<td>36</td>
</tr>
<tr>
<td>Table</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>14</td>
<td>Leaf area index of alfalfa as affect by cultivars</td>
<td>37</td>
</tr>
<tr>
<td>15</td>
<td>Effect of water quality on leaf area index of alfalfa cultivars</td>
<td>38</td>
</tr>
<tr>
<td>16</td>
<td>Effect of weeding on leaf area index of alfalfa cultivars</td>
<td>40</td>
</tr>
<tr>
<td>17</td>
<td>Leaf to stem ratio of alfalfa as affected by cultivars</td>
<td>41</td>
</tr>
<tr>
<td>18</td>
<td>Effect of water quality on leaf to stem ratio of alfalfa cultivars</td>
<td>42</td>
</tr>
<tr>
<td>19</td>
<td>Effect of weeding on leaf to stem ratio of alfalfa cultivars</td>
<td>43</td>
</tr>
<tr>
<td>20</td>
<td>Fresh yield of alfalfa (t/ha) as affected by cultivars</td>
<td>44</td>
</tr>
<tr>
<td>21</td>
<td>Effect of water quality on forage fresh yield (t/ha) of alfalfa cultivars</td>
<td>46</td>
</tr>
<tr>
<td>22</td>
<td>Effect of weeding on forage fresh yield (t/ha) on alfalfa cultivars</td>
<td>47</td>
</tr>
<tr>
<td>23</td>
<td>Dry yield of alfalfa (t/ha) as affected by cultivars</td>
<td>48</td>
</tr>
<tr>
<td>24</td>
<td>Effect of water quality on forage dry yield (t/ha) of alfalfa cultivars</td>
<td>49</td>
</tr>
<tr>
<td>25</td>
<td>Effect of weeding on forage dry yield (t/ha) on alfalfa cultivars</td>
<td>51</td>
</tr>
<tr>
<td>26</td>
<td>Effect of water quality and weeding on number of racemes per plant of alfalfa cultivars</td>
<td>52</td>
</tr>
<tr>
<td>27</td>
<td>Effect of water quality and weeding on number of pods per raceme of alfalfa cultivars</td>
<td>53</td>
</tr>
<tr>
<td>28</td>
<td>Effect of water quality and weeding on number of seed per raceme of alfalfa cultivars</td>
<td>55</td>
</tr>
<tr>
<td>Table</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>29</td>
<td>Effect of water quality and weeding on 1000-seed weight of alfalfa cultivars</td>
<td>56</td>
</tr>
<tr>
<td>30</td>
<td>Effect of water quality and weeding on seed yield of alfalfa cultivars</td>
<td>57</td>
</tr>
<tr>
<td>31</td>
<td>Effect of water quality and weeding on crude protein content of alfalfa cultivars</td>
<td>59</td>
</tr>
<tr>
<td>32</td>
<td>Effect of water quality and weeding on crude fiber content of alfalfa cultivars</td>
<td>60</td>
</tr>
<tr>
<td>33</td>
<td>Effect of water quality and weeding on number of weeds per unit area (used plants/feddan) of alfalfa cultivars</td>
<td>61</td>
</tr>
</tbody>
</table>
ACKNOWLEDGEMENT

My utmost gratitude and sincere thanks to my supervisor Dr. Awad Osman Mohamed Abu Suwar for his great assistance, guidance of unlimited support throughout the course of this study.

My thanks are extended to all members of Agronomy Department, Faculty of Agriculture, University of Khartoum.

The efforts of Miss. Bilghies in the typing of this thesis are highly appreciated.

Special thanks and sincere appreciation to my wife, my brothers and sisters and my niece for their unlimited moral support.
ABSTRACT

A field experiment was carried out during 2005/06 and 2006/07 seasons as: the Demonstration Farm of the Faculty of Agriculture, Shambat, to study the effect of water quality and weeding on the growth, yield, quality and seed production of three alfalfa (*Medicago sativa* L.) cultivars.

The treatments in this study included three alfalfa cultivars: a local cultivar, Hegazi and two exotic cultivars, Cuf101 and Siriver. The water treatments were: bore hole water, river water with screen mesh at the entrance of plots and river water without screen mesh. Three levels of weeding were applied; monthly weeding, every two months and every three months.

The treatments were assigned in a split-split plot design with watering as the main plots, weeding as the sub-plots and cultivars as the sub-sub-plots. The treatments were replicated four times.

The parameters studied were: number of nodules, nodule fresh and dry weights, number of effective nodules, plant density, plant height, shoot/root ratio, leaf area index, leaf to stem ratio, forage fresh of dry yields, number of racemes per plant, number of pods per raceme, number of seeds per pod, 1000-seed weight, total seed yield, crude protein and crude fiber content and number of weeds per unit area.

The two introduced cultivars were significantly better than the local one in nodule fresh and dry weights, number of effective nodules, plant density, plant height, shoot/root ratio, leaf area index, leaf to stem ratio, forage fresh of dry yields, number of racemes per plant, number of
pods per raceme, total seed yield and crude protein content. The three cultivars were similar in number of nodules per plant, number of seeds per pod, 1000-seed weight and number of weeds per unit area, whereas, the local cultivar gave a higher crude fiber content.

Irrigation water treatments were not significantly different in nodulation, number of pods per raceme, number of seeds per pod and crude protein and fiber contents. However, the river screened water treatment was significantly superior in plant density, plant height, shoot/root ratio, leaf area index, leaf to stem ratio, forage fresh and dry yields, number of racemes per plant, 1000-seed weight, total seed yield and number of weeds per unit area. In all these parameters, the river water without screening treatment recorded the lowest estimates.

Monthly weeding treatment showed a significant increase in: plant height, shoot/root ratio, leaf area fresh and dry yields, 1000-seed weight, total seed yield and number of weeds per unit area than the other weeding levels.
between the years 2005/06 and 2006/07.

The results of the study are indicated as follows:

The irrigation treatments affected:

- The growth stage and:
- The number of harvested ears.

The results of the study show a significant increase in:

- The number of productive ears,
- The number of grains per ear,
- The number of productive ears per row,
- The number of grains per row,
- The number of productive ears per row,
- The number of grains per row,
- The number of productive ears per row,
- The number of grains per row,
نبات، في بذرية الألف وزن القرن، في البذور عدد وحدة في الحشائش وعدد الألفية المساحة يمكن أن بذرة، بينما.

في القرن عدد الجذرية، العقد في معنى فروقات الألفية المختلفة، وردامات تظهر لم، animate الألحمية، النور، تفوق وشبهية، بادل النظام، تمزق، الآخرين، منع، تفوق، ظهرت نهارية، إزالة الطول لنبات، العربية، الأوراق، رطبة الإنتاج، لسائل، الأوراق، إنتاج البذرة، الألف وزن.

في الأنهار بميته المعاملة سجلت الصفة هذه التقديرات، كل أقل تنقيحة دون البداية.

بادل الآخرين بيدل، النور، الأوراق، جذور، الزهيرة، المساحة النورية، وحدة في الحشائش وعدد البذور إنتاجية بذرة، الألف وزن.

.319، 418، 518، 618، 718، 818، 918، .
CHAPTER ONE
INTRODUCTION

The estimated livestock number in Sudan is about 165 millions heads, which is equivalent to about 86 million animal units (AOAD, 2001). Due to range vegetation degradation and desertification, the total dry matter production for livestock feeding is negative. Currently, the total dry matter production from natural range vegetation, crop residues, green forage, and concentrated feed was estimated to amount only 104.8 million tons, while to total dry matter required support the livestock feeding amount to almost 213.2 million tons. The current feed gap in livestock feed was estimated to amount only 104.4 million tons, which represent almost 50% of the total requirement of livestock feed (Abu Suwar and Darag, 2002).

Currently the government comprehensive strategy is directed toward the increase of forage production to almost 9 millions instead of 4 million tons to correct the livestock feed balance.

To cope with the increase in animal resources and the shortage in forage produced in natural rangelands, expansion and improvement of irrigated forage become a necessity.

Alfalfa (*Medicago sativa* L.) is the most important forage crop grown in the Sudan. It is a good quality forage for livestock of all classes. No other forage crop is better choice for soil improvement than alfalfa
because of alfalfa’s ability to add high levels of nitrogen, improve soil tilth and reduce soil erosion (Jacobs, 1984).

The total area cultivated by the crop in Sudan is about 125000 feddans, the annual production is estimated to be about 1,002,500 tons green forage and the crop contributes by about 94% of the total irrigated forages in the country (Abu Suwar, 2004).

Alfalfa is exclusively grown under irrigation, particularly along the Nile from Khartoum State northwards and since it is sensitive to humidity Sinnar is its southern limit. In the Sudan, the crop is left to grow for 2 – 4 years giving a cut every three weeks on average. At the end of the third to fourth year, the crop may be left to produce seeds during the hot dry period, from March to May (Nayel and Khidir, 1995).

Alfalfa has many advantages that no other forage crop has (Abu Suwar, 2004). These are: its hay is of a high nutritive value for all classes of livestock, its high protein and carotene and low fiber content, contains most vitamins including vitamin A₁, has the xanthophyll pigment, which is essential in poultry feed, important for honey bee production, its sprout is healthy for vegetarians and is a good substitute for animal proteins. The crop worldwide distribution is attributed to a number of characteristics such as longevity, symbiotic nitrogen fixation, high yield of good quality herbage, suitability for mechanical harvesting, good recovery after cutting or grazing and adaptability to different climatic and soil conditions. In all parts of the world alfalfa is recognized as having the capability of producing from 100 to 200 kg/ha nitrogen for the use of
the subsequent cash crops such as cotton, maize and wheat (Marble, 1984).

The production of alfalfa in Sudan encounters many problems such as: scarcity in improved seeds, little attention in breeding research of the crop, limited information pertaining to the agronomy of its production, unawareness of seed inoculation techniques, absence of utilizing and preserving methods of the crop, continuous cultivation of the local variety (Hegazi) disregarding introducing promising cultivars, absence marketing channels and weed infestation.

The most serious problem in alfalfa production is that during damira season, the forage yield dramatically decreases. This decrease may continue for three to four months, and is accompanied by severe weed infestation. High weed infestation especially during damira time was thought to be due to the fact that river water transports weed seeds to the field. Moreover, neglect of weeding operation throughout the life of the plant may be another cause of weed infestation (Abu Suwar, personal communication).

The main objective of this study was, therefore, to investigate the effect of water quality and weeding on the growth, yield, quality and seed production of three alfalfa cultivars.
CHAPTER TWO
LITERATURE REVIEW

2.1 Crop requirements and establishment

Alfalfa is well adapted to a wide range of soil and climatic conditions. It prefers deep, well drained loam soils. Poor drainage promotes roots and crown diseases, inhibits nitrogen fixation and reduces winter survival (Smith et al., 1999). The authors reported that a soil pH between 6.5 and 8.0 is satisfactory for optimum forage production. Caddel et al. (2001) on the other hand, stated that all soil textures (sands, loams and clays) can be used for alfalfa, however, soils should be well drained to allow oxygen to roots for nitrogen fixation by rhizobium. Soils with pH near neutral favour nutrient availability and rhizobium activity for good alfalfa production.

Lucerne (alfalfa) is best grown under dry shiny climates as in north and central Sudan (Abu Suwar, 2005). Humid weather is not suitable. The optimum night and day temperatures are 15° and 30°C, respectively and the crop growth rate declines at temperatures lower than 10°C or above 40°C.

Since alfalfa seeds are very small, care should be given in preparing the seedbed. An ideal seedbed is firm on the surface but loose in the root zone to allow rapid root penetration (Caddel, 1996). Seedbed preparation should be done when there is sufficient moisture in the soil so that it crumbles when worked. Good surface drainage is critical for
establishment and survival of alfalfa since the crop can not survive in water-logged soils.

The long-term productivity of an alfalfa field depends on successful establishment during the year it is seeded (Smith et al., 1999). To ensure the success of seeding, it is necessary to avoid planting on sites with poor surface drainage, infested with perennial or noxious weeds and to rotate the field to different crop for one season or allow it on fallow for most of the growing season after the old stand is destroyed.

Seeding rate depends on the quality and viability of seeds. It is a critical component of alfalfa crop yield as it affects the total dry mater yield (Jaume et al., 2008). Hall et al. (2004) found that, alfalfa seeding rate greatly affected the number of surviving plants after one year. Increasing seeding rates resulted in nearly a linear increase in plant densities (Hall, 1993; Kephart et al., 1992; Nelson et al., 1996, 1998 and 2001). Higher seeding rates had greater plant mortality rates (40%). The authors recommended that the optimum seed rate for alfalfa production is 17 kg/ha. In Sudan, Nayel and Khidir (1995) reported that the optimum seed rate of lucerne for fodder production is 40 kg/ha when sown on ridges of heavy day soils and 30 kg/ha for seed production. Khair (1992), however, realized that seed rate over the range 12-70 kg/ha had no significant effects on the dry matter production and thus the seed rate could be reduced to 12 kg/ha or even lower without considerable effect on yield and seed production.
The results of inoculating alfalfa seeds with rhizobia have been inconsistent, in some instances there had been a significant increase in nodule number, nodule dry weight, dry matter yield and crude protein content (Lim et al., 1994 and Russelle and Birr, 2004), whereas in others no response was found (Kots et al., 1995). On the other hand, El Sheikh et al. (2006) found that alfalfa inoculation with *Rhizoloium melilotti* improved shoot fresh and dry weights, root fresh and dry weights, nodule number, nodule dry weight, plant density and forage yield. Weiser et al. (1985) and Rice (2001) reported that inoculation increased nodule dry weight and number of nodules of alfalfa. Abu Suwar and Mohamed (1997) pointed out that in fertilized or inoculated treatments, the seed yield components and final seed yield increased considerably compared to that of the control. The older stands had a lower plant density than the younger stands as the number and effectiveness of rhizobium decreases with the age of alfalfa (El Sheikh et al., 2006 and Abu Suwar and Mohamed, 1997). Inoculating lucerne (alfalfa) with *Rhizobium melilotti* is necessary (Abu Suwar, 2004).

### 2.3 Varieties

As alfalfa cultivars have become more numerous in recent years, the issue of precision of alfalfa forage yield determinations becomes more important (Michael et al., 2000). Humpheries and Hughes (2006) reported that alfalfa varieties differ in yield, quality, leaf to stem ratio and stem thickness. Imperative yield trials, Lowe et al. (1985) found that
many of the newly released varieties had significantly yielded more and persisted longer than the regularly local varieties. Billman et al. (1991) stated that different cultivars of alfalfa are significantly different in their total yield. McQueen and Belanger (1994) reported no differences between leaf to stem ratio of alfalfa cultivars, but they later reported a significant difference in stem digestibility and number of leaves per plant. There was no significant difference between alfalfa cultivars in morphological development, but they differ in forage quality (Marvin et al., 2000). Similarly, Griffin et al. (1994); Sanderson and Wedin (1988) and Kalu and Fick (1983) stated that, alfalfa cultivars differ in their quality due to differences in cell wall chemistry.

In Sudan, Abu Suwar (2004) stated that, variety selection is one of the most important alfalfa management decisions. The selected variety should have: high yielding capacity, good persistency, tolerance to frequent cutting, drought, salinity and frost, higher competition ability especially during the first year and high seed yielding capacity. The author mentioned that most of the varieties grown in the Sudan are local ones, but recently introduced varieties: Siriver, Cuf101 and spreader II have been widely cultivated and showed excellence. Abu Suwar and Mohamed (1997) reported that an introduced cultivator, Pioneer 5929, out-scored the local cultivar, Hegazi in yield components, but the latter gave higher thousand seed weight and total seed yield.
2.4 Fertilizer requirements

Alfalfa fertilizer requirements must be determined through soil analysis before planting. The crop continuously depletes soil nutrients. Each ton of hay contains about 50 lb of nitrogen, 10 lb of phosphorus (P₂O₅) and 60 lb of potassium (K₂O), (Smith et al., 1999).

Alfalfa seedling depends on nitrogen until nodulation occurs. Abu Suwar (2005) reported that 40 to 80% of nitrogen requirements of lucerne is obtained by nodules, therefore the crop needs a little amount of nitrogen (40 lb N\feddan). However, phosphorus is usually the most limiting nutrient.

2.5 Irrigation

Alfalfa ranks highly among other forage for quality and yield. It has a higher water requirements compared to other irrigated crops. These characteristics combine to make it one of the crops most widely grown under irrigation.

Alfalfa is relatively drought tolerant, but its growth depends on available soil water. Therefore, in any given setting, dry matter yield is proportional to the amount of water used by the crop provided there are no major nutrient limitations (Smith et al., 1999). Though alfalfa requires much water per unit dry matter produced than any other commonly grown field crops, the efficiency of water decreases as evaporation demand of the environment increases (Puech et al., 1977).

The amount of water applied is largely affected by the length of the growing season, the number of cutting and climatic factors such as
temperature, evaporation, soil precipitation and wind velocity (Salisbury and Ross, 1982). On the other hand, Abu Suwar (2005) stated that the amount of water required by lucerne depends on the growing season, crop age, vegetative cover or leaf area and soil type. The author also reported that the crop requires fewer amounts of irrigation water during the period from July to October because of rainfall and crop dormancy.

2.6 Weeding

Alfalfa plants are more likely infested by annual weeds, which cause serious problems in established stands. Perennial weeds are also common problems in established alfalfa (Smith et al., 1999).

Weed management is important for decreasing competition with alfalfa and for increasing alfalfa yield and quality during the establishment year (Chapko et al., 1991 and Hall et al., 1995). Good crop management represents about 75-90% of forage weed control program (Doll, 2000), weed control during legume establishment is critical to obtain productive stand (Zollinger and Meyer, 1996). However, Stout et al. (1992) found that weed control during the establishment year increased alfalfa shoot weight and leaf number. Beck et al. (1999) reported that, weeds in new alfalfa stands or in established stands decrease yield. Michael et al. (2002) concluded that, grass weeds reduce both yield and quality of alfalfa. Doll (2000) reported that, weeds reduce alfalfa yield and quality to varying extents depending on weed species, density and the stage of weed growth.
In the Sudan, Abu Suwar (2004) reported that, weed control is important for alfalfa persistence, since weeds reduce the crop yield and may cause crop failure because of the poor alfalfa competitive ability. The author mentioned that, the most serious weeds that infest alfalfa are the perennial grasses like: Bermuda grass (*Cynodon dactylon*), nutgrass (*Cypetus rotundus*) and Kleberg’s blue stem (*Dicanthium annulatum*). The annual broad leaf weeds e.g purslane (*Portulaca oleracea*) and tellet (*Solanum dubium*) have less effect on the crop. The successful alfalfa weed control program depends on eradication of weeds and their seeds in the soil before planting, by disc ploughing or prewatering to remove the growing weeds. Herbicides can also be used.

### 2.7 Seed production

The dual use of alfalfa plants to produce both forage and seed, each at in its appropriate season, would be both beneficial to the health of stands and income earning potential. Increasing the health of stands is by increasing the carbohydrates storage in the roots 2 to 3 months period of accumulation during seed setting and maturation and increase plant vigor by increasing the ability of the crop to compete weeds (Marble, 1989).

Although, alfalfa seed production has become a secondary importance to forage production, the variation in the environmental conditions such as soil texture, rainfall, strong wind and seasonal temperature variation, which are unfavourable for consistent seed production, the need for proper production techniques would be of great importance (Marble, 1984).
The food and Agricultural Organization (FAO, 1989) summarized the climatic conditions favouring alfalfa seed production in a growing period of at least 150 days during flowering. These are: average temperature between 24°C and 35°C during the day and above 18°C at night, relatively dry air, less than 50% relative humidity both day and night, and bright sunny and wind-free days with a minimum of cool. The FAO report also indicated that the best time to produce alfalfa seeds would be mid April to late May.

Irrigated dry and semi-dry regions are optimal for alfalfa seed production (Abu Suwar, 2004). In the Sudan, the crop is left to grow for 2-4 years for forage production, then the crop may be left to produce seeds during the hot period, from March to May (Nayel and Khidir, 1995). The authors reported that seed yield was 145.8 kg/ha whereas Abu Suwar and Mohammed (1997) estimated it as 99.3 kg/ha. Hamid (1997) and Mustafa (1996) found that total seed yield was 136.7 kg/ha and 152.9 kg/ha, respectively.

2.8 Forage harvest

The maximum returns from alfalfa crop largely depend on harvesting management, the seasonal production, quality and plant survival, which are influenced by the number of cuttings, while plant vigor, rate of recovery following cutting, degree of weediness and resistance to diseases are severely affected by the frequency of harvest (Marble, 1989). The stage of maturity at harvest and frequency of cutting...
can also affect the quality of the final product and influence the productivity.

Norris and Debra (1991) advice that the cutting intervals should be long enough to maintain proper crop stand and density with less invasion of weeds. Sundararaj et al. (1980) pointed out that, the early cutting of alfalfa just before flowering stage gave better qualities of hay and if the crop was cut in full bloom, yields were higher, but very late cutting may lead to loss of leaves, stems become more woody and reduction in alfalfa nutritive value. Cutting lucerne at the pre-flower bud stage rather than 10% bloom increased protein content up to 24% and digestibility with only moderate decline in yield. More frequent cutting, however, was found to decrease plant density and increase the proportion of weeds invasions (Slarkes and Mason, 1987). Ta and Faris (1987) suggested that, harvesting of alfalfa at mid-bloom stage increased the total herbage and nitrogen concentration compared to early bloom stage.

Abu Suwar (2004) reported that, early flowering stage (10% flowering) is the optimum time to harvest alfalfa, because of its higher protein content. Delaying the harvest resulted in a decrease in protein content and an increase in fiber content. However, it is suitable to harvest the crop when 10 – 50% of the plants flowered. Nayel and Khidir (1995) and Abu Suwar (2004) stated that, the cutting interval of alfalfa is about three weeks, depending on the climatic conditions prevailing.
2.9 Forage yield

Productivity of lucerne depends largely on soil type, the growing season, irrigation method, the cultivar, plant density, cutting intervals and the area of production (Abu Suwar, 2004). Regarding these factors the author reported that, yield of the crop declines in saline soils and at the end of summer and during autumn. Slarke and Mason (1987) reported that, cutting stage had a greater effect on yield than did cultivar.

Khair (1992) pointed out that, the local cultivar Hegazi out yielded the introduced Pioneer when the crop was cut at an interval of 2 or 4 weeks, but a reverse effect occurred when the crop was cut every eight weeks. On the other hand, Mohamed (2000) found that, Hegazi showed a quick recovery after cutting, while Pioneer took relatively longer time to recover.

The local cultivar was superior to the introduced one in forage fresh and dry yields (Ali et al., 1998; Mohamed, 2000 and Fadul, 2001). The forage fresh yield of alfalfa was found to be 6.38 and 7.82 tons/ha for Hegazi and Pioneer, respectively (Mohamed, 2000). Whereas, Fadul (2001) estimated it as 9.81 and 5.22 tons/ha for the same cultivars. El Sheikh et al. (2006) reported that, the average forage yield of the crop was estimated by about 11.9 tons/ha. Productivity of lucerne on the dry matter basis recorded 10.4 tons/ha from 12 cuts of the year (Nayel and Khidir, 1995), 1.91 to 1.60 tons/ha (Mohamed, 2000) and 2.53 to 1.98 ton/ha (Fadul, 2001).
CHAPTER THREE
MATERIALS AND METHODS

3.1 Site description

3.1.1 Location and climate

A field experiment was carried out during 2005/06 and 20006/07 seasons to study the effect of water quality and weeding on the growth, yield, quality and seed production of three alfalfa (Medicago sativa L.) cultivars.

The experiment was conducted in the Experimental Farm of the Faculty of Agriculture, Shambat, latitude 15°40′N, longitude 32°32′E and 380 meters above sea level. The Soil is a cracking clay and moderately alkaline (pH 7.8 – 8.5) and the climate is semi-arid with a mean rainfall estimated by 67.8 mm (Sudan Meteorological Department, 1993). The mean relative humidity, temperature and rainfall at Shambat during the experiment are shown in Appendix 1.

3.1.2 Land preparation

The experimental area was disc ploughed, disc harrowed to crush clods and levelled out to maintain a well levelled seedbed and then ridged (70 cm a part). Individual plot size was 4 × 4 m with five ridges.

3.1.3 Treatments and design

The treatment in this study included three alfalfa cultivars, Hegazi (C₁), which is commercially grown in Sudan and two introduced
cultivars, Cuf101 (C\textsubscript{2}) and Siriver (C\textsubscript{3}). The water treatments were: bore hole water (I\textsubscript{1}), river water with screen mesh at the entrances of plots (I\textsubscript{2}) and river water without screen mesh (I\textsubscript{3}). The three levels of weeding were: monthly weeding (W\textsubscript{1}), every two months (W\textsubscript{2}) and every three months (W\textsubscript{3}). The later level W\textsubscript{3} was designated as the control. The treatments were arranged in a split-split plot design with four replicates. The water treatments were assigned to the main plots whereas the weeding levels and cultivars were allocated to the subplots and the sub-sub subplots, respectively.

3.2 Cultural practices

3.2.1 The seeds

The seeds of the cultivars Hegazi and Cuf101 were obtained from the Agronomy Dept., Faculty of Agriculture, Khartoum University, while the seeds of the cultivars Siriver were obtained from the Arab Company for Production and Marketing Fodder, Atbara, Sudan.

The crop was sown on the third week of November, after inoculating the seeds with \textit{Rhizobium melilotti}, by drilling on the side of the ridge at a rate of 20 kg\textperthousand feddan. The first irrigation was given immediately after sowing then the crop was watered every 12 – 14 days.

3.2.2 Weeding

Two hand weedings were carried out, one month from sowing and after the first cut of the whole experiment, thereafter weeding treatments were applied.
3.3 Parameters

The following parameters were measured during the course of this study.

3.3.1 Nodulation

Measurements of these characters were taken after 45 days from sowing.

3.3.1.1 Number of nodules per plant

Ten plants, from the four outer ridges were randomly selected from each plot. Nodules in each plant were counted and then the average number of nodules per plant was determined.

3.3.1.2 Nodule fresh and dry weights

The nodules used in the above parameter were weighed fresh, put in an oven at 80°C for 48 hours, then means nodule fresh and dry weights were determined.

3.3.1.3 Nodule effectiveness

Red coloured nodules (effective ones) were counted in each treatment by microscopic examination.

3.3.2 Growth attributes

These parameters were measured each time at harvest.
3.3.2.1 **Plant density**

Plants in an area of 0.7 m\(^2\) from the middle ridge of each plot were counted to determine number of plants/ m\(^2\).

3.3.2.2 **Plant height (cm)**

Ten plants were randomly taken from each plot and measured from the soil surface to the plant tip, then average plant height was recorded.

3.3.2.3 **Leaf area index (LAI)**

Leaf area index was determined according to Watson and Watson (1953) method. Ten leaves were randomly taken from each plot. Leaves were punctured, put in an oven at 80\(^\circ\)C for 48 hours and then dry weights of punctured leaves and discs were determined using mettler balance. The leaf area was calculated as follows:

\[
\text{Leaf area} = \frac{\text{Weight of leaf} \times \text{area of disc}}{\text{Weight of disc}}
\]

Then, leaves in an area of 0.7 m\(^2\) were counted and their area was calculated using the above formula. Finally, leaf area index was determined according to the formula:

\[
\text{Leaf area index (LAI)} = \frac{\text{Area of leaves}}{\text{Area of land occupied by leaves}}
\]

3.3.2.4 **Leaf to stem ratio**

Ten plants were randomly selected clipped from each plot and the leaves were separated from the stem and branches. The two components
were put in an oven at 80°C for 48 hours to get their dry weights, then the ratio of leaves to stem was determined on dry basis.

### 3.3.2.5 Shoot/root ratio

Plants of the previous attribute were used to estimate this character. Shoots and roots were put in an oven at 80°C for 48 hours to get their dry weights, then shoot/root ratio was determined on dry basis.

### 3.3.3 Forage yield

#### 3.3.3.1 Fresh yield

The whole plot for each treatment was cut and the fresh weight of the plants was determined immediately using spring balance. From this, forage fresh yield per hectare was calculated.

#### 3.3.3.2 Dry yield

Plants within an area of 0.7 m² from the middle ridge of each plot were cut and air-dried to determine their dry weights. From this, forage dry yield per hectare was calculated.

### 3.3.4 Seed yield

These attributes were taken during the last harvest.

#### 3.3.4.1 Number of racemes per plant

In each plot, ten plants were randomly selected and tagged. Racemes on these plants were counted at an interval of seven days, then the average number of racemes per plant was recorded.
3.3.4.2 Number of pods per raceme

The ten tagged pants were collected separately and the pods were counted. Then the average number of pods per raceme was recorded.

3.3.4.3 Number of seeds per pod

Seeds in the pods use in measuring the above attribute were counted and the mean number of seeds per pods was determined for each treatment.

3.3.4.4 Thousand seed weight

A sample of 4000 seeds obtained from pods, randomly taken from each plot, was used for determining this parameter. Sub-samples of 1000 seeds were taken from each main sample and their weight was determined. Then mean 1000-seed weight for each treatment was obtained.

3.3.4.5 Seed yield per plant

Seeds from pods of tagged plants mentioned above were weighed to determine seed yield per plant.

3.3.4.6 Total seed yield

Pods in an area of 0.7 m² were collected from each plot and threshed, then the seeds were weighed. From this, seed yield per hectare was calculated.
3.3.5 Proximate analysis

3.3.5.1 Crude protein and crude fiber

These parameters were determined according to the method described by AOAC (1984). Two samples each weighing 0.2 gm and 2.0 gm were taken from each plot to estimate crude protein and crude fiber.

3.3.6 Number of weeds per unit area

Number and types of weeds in each plot were determined each time at harvest, then number of weeds per unit area was estimated.

3.3.7 Data analysis

Data obtained were statistically analysed using the analysis of variance as described by Gomez and Gomez (1984). For mean separation Duncan Multiple Range Test was used.
CHAPTER FOUR
RESULTS

4.1 Nodulation

4.1.1 Number of nodules

Analysis of variance showed that there were no significant differences among treatments and their interactions in this character (Table 1).

4.1.2 Nodule fresh weight

Results showed that there was a significant difference between cultivars in nodules fresh weight where (C2) and (C3) were similar but significantly greater than (C1), (Table 2).

Water treatments, weeding levels and all treatment interactions had no significant effects on this parameter (Table 2).

4.1.3 Nodule dry weight

This character was significantly affected among alfalfa cultivars. The cultivars (C2) and (C3) were similar, but had greater nodule dry weights than (C1), (Table 3).

Irrigation treatments, weeding and treatment interactions did not affect this parameter (Table 3).

4.1.4 Number of effective nodules

Effective nodules differed significantly among alfalfa cultivars. The highest number of effective nodules was obtained by (C3) followed by (C2) then (C1), (Table 4).
Table 1. Effect of water quality and weeding on number of nodules of alfalfa cultivars

<table>
<thead>
<tr>
<th>Treatments</th>
<th>W₁</th>
<th>W₂</th>
<th>W₃</th>
<th>Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C</td>
</tr>
<tr>
<td>I₁</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C₁</td>
<td>31.24</td>
<td>31.01</td>
<td>31.55</td>
<td></td>
</tr>
<tr>
<td>C₂</td>
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<td>30.40</td>
<td>33.60</td>
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</tr>
<tr>
<td>C₃</td>
<td>32.77</td>
<td>33.57</td>
<td>33.57</td>
<td></td>
</tr>
<tr>
<td>I₂</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C₁</td>
<td>32.20</td>
<td>32.75</td>
<td>32.75</td>
<td></td>
</tr>
<tr>
<td>C₂</td>
<td>32.63</td>
<td>34.58</td>
<td>34.58</td>
<td></td>
</tr>
<tr>
<td>C₃</td>
<td>32.51</td>
<td>35.24</td>
<td>35.24</td>
<td></td>
</tr>
<tr>
<td>I₃</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C₁</td>
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<td>32.79</td>
<td>32.79</td>
<td></td>
</tr>
<tr>
<td>C₂</td>
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<td>35.53</td>
<td>35.53</td>
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</tr>
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<td>C₃</td>
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<td>33.02</td>
<td>33.02</td>
<td></td>
</tr>
<tr>
<td>Means</td>
<td>32.92²</td>
<td>33.21²</td>
<td>33.21²</td>
<td></td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.

Lsd I  = 3.25
Lsd C  = 2.98
Lsd W  = 3.18
Table 2. Effect of water quality and weeding on nodule fresh weight of alfalfa cultivars

<table>
<thead>
<tr>
<th>Treatments</th>
<th>W₁</th>
<th>W₂</th>
<th>W₃</th>
<th>Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C</td>
</tr>
<tr>
<td>I₁</td>
<td></td>
<td></td>
<td></td>
<td>C₁</td>
</tr>
<tr>
<td>C₁</td>
<td>3.71</td>
<td>3.63</td>
<td>3.58</td>
<td></td>
</tr>
<tr>
<td>C₂</td>
<td>4.23</td>
<td>4.54</td>
<td>4.28</td>
<td></td>
</tr>
<tr>
<td>C₃</td>
<td>4.36</td>
<td>4.46</td>
<td>4.42</td>
<td></td>
</tr>
<tr>
<td>I₂</td>
<td></td>
<td></td>
<td></td>
<td>C₂</td>
</tr>
<tr>
<td>C₁</td>
<td>3.72</td>
<td>3.54</td>
<td>3.48</td>
<td></td>
</tr>
<tr>
<td>C₂</td>
<td>4.26</td>
<td>4.19</td>
<td>4.62</td>
<td></td>
</tr>
<tr>
<td>C₃</td>
<td>4.72</td>
<td>4.34</td>
<td>4.21</td>
<td></td>
</tr>
<tr>
<td>I₃</td>
<td></td>
<td></td>
<td></td>
<td>C₃</td>
</tr>
<tr>
<td>C₁</td>
<td>3.62</td>
<td>3.44</td>
<td>3.29</td>
<td></td>
</tr>
<tr>
<td>C₂</td>
<td>4.56</td>
<td>4.40</td>
<td>4.62</td>
<td></td>
</tr>
<tr>
<td>C₃</td>
<td>4.28</td>
<td>4.58</td>
<td>4.78</td>
<td></td>
</tr>
<tr>
<td>Means</td>
<td>4.16ᵃ</td>
<td>4.12ᵃ</td>
<td>4.14ᵃ</td>
<td></td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.

Lsd I = 0.73
Lsd C = 0.64
Lsd W = 0.86
Table 3. Effect of water quality and weeding on nodule dry weight of alfalfa cultivars

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<th>Treatments</th>
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<th>W&lt;sub&gt;2&lt;/sub&gt;</th>
<th>W&lt;sub&gt;3&lt;/sub&gt;</th>
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<td></td>
<td></td>
<td>C</td>
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<td>I&lt;sub&gt;1&lt;/sub&gt;</td>
<td>1.21</td>
<td>1.17</td>
<td>1.16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C&lt;sub&gt;2&lt;/sub&gt;</td>
<td>1.38</td>
<td>1.48</td>
<td>1.42</td>
</tr>
<tr>
<td></td>
<td>C&lt;sub&gt;3&lt;/sub&gt;</td>
<td>1.42</td>
<td>1.45</td>
<td>1.44</td>
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<td>I&lt;sub&gt;2&lt;/sub&gt;</td>
<td>1.20</td>
<td>1.15</td>
<td>1.12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C&lt;sub&gt;2&lt;/sub&gt;</td>
<td>1.40</td>
<td>1.38</td>
<td>1.51</td>
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<td>I&lt;sub&gt;3&lt;/sub&gt;</td>
<td>1.16</td>
<td>1.12</td>
<td>1.07</td>
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<tr>
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<td>1.50</td>
<td>1.44</td>
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<tr>
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<td>1.42</td>
<td>1.49</td>
<td>1.56</td>
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<tr>
<td>Measns</td>
<td>1.36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.34&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.35&lt;sup&gt;a&lt;/sup&gt;</td>
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</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT. Lsd I = 0.48, Lsd C = 0.21, Lsd W = 0.46.
Table 4. Effect of water quality and weeding on number of effective nodules of alfalfa cultivars

<table>
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<tr>
<th>Treatments</th>
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<th>W&lt;sub&gt;2&lt;/sub&gt;</th>
<th>W&lt;sub&gt;3&lt;/sub&gt;</th>
<th>Means</th>
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</thead>
<tbody>
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<td>18.34</td>
<td>17.51</td>
<td>C&lt;sub&gt;1&lt;/sub&gt; 16.47&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>C&lt;sub&gt;2&lt;/sub&gt; 20.11</td>
<td>18.15</td>
<td>19.83</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C&lt;sub&gt;3&lt;/sub&gt; 21.20</td>
<td>19.18</td>
<td>19.89</td>
<td></td>
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<tr>
<td>I&lt;sub&gt;2&lt;/sub&gt;</td>
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<td>16.13</td>
<td>15.14</td>
<td>C&lt;sub&gt;2&lt;/sub&gt; 19.48&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>C&lt;sub&gt;2&lt;/sub&gt; 21.84</td>
<td>21.27</td>
<td>18.78</td>
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<td></td>
<td>C&lt;sub&gt;3&lt;/sub&gt; 21.76</td>
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</tr>
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<td></td>
<td>C&lt;sub&gt;2&lt;/sub&gt; 19.24</td>
<td>18.93</td>
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<td>C&lt;sub&gt;3&lt;/sub&gt; 22.16</td>
<td>20.86</td>
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<td><strong>Means</strong></td>
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<td>18.83&lt;sup&gt;a&lt;/sup&gt;</td>
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</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.

Lsd I = 3.15
Lsd C = 2.24
Lsd W = 2.96
Irrigation, weeding and treatment interaction showed no significant differences in this attribute (Table 4).

4.2 Growth parameters

4.2.1 Plant density

As shown in Table 5 results showed that cultivars caused a significant effect on plant density in 10 out of 18 sampling occasions. The highest mean plant densities were recorded by the cultivars (C₃) and (C₂), whereas in same occasions the cultivars (C₁) showed slight but not significant increase in this parameter.

Water treatments also showed a significant effect on plant population in 8 out of 18 sampling occasions in which (I₁) and (I₂) recorded higher mean plant densities than (I₃), (Table 6). Weeding levels, on the other hand, had no significant effect on this character (Table 7).

4.2.2 Plant height

Statistical analysis revealed that there was a significant variation among cultivars in plant height of alfalfa throughout the experimental period (Table 8).

The cultivars (C₂) and (C₃) were not significantly different in plant height in most of the sampling occasions, but they recorded higher mean plant height than (C₁), (Table 8).

Irrigation water treatments significantly affected plant height of alfalfa cultivars in 10 out of 18 occasions throughout the study (Table 9). In these occasions, the treatment (I₂) gave higher mean plant height than other irrigation treatments.
Table 5. Plant density of alfalfa (plants/m²) as affected by cultivars

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
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<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>219.3a</td>
<td>319.1b</td>
<td>310.7b</td>
<td>295.3b</td>
<td>279.3b</td>
<td>241.6a</td>
<td>249.2a</td>
<td>197.2a</td>
<td>131.5a</td>
<td>129.4a</td>
<td>176.8a</td>
<td>354.1a</td>
<td>316.5b</td>
<td>298.7b</td>
<td>296.3b</td>
<td>251.5b</td>
<td>212.6b</td>
<td>208.6b</td>
</tr>
<tr>
<td>C2</td>
<td>222.8a</td>
<td>415.6a</td>
<td>405.7a</td>
<td>403.4a</td>
<td>380.6a</td>
<td>230.7a</td>
<td>228.8a</td>
<td>180.7a</td>
<td>119.4a</td>
<td>116.3a</td>
<td>198.7a</td>
<td>381.2a</td>
<td>436.4a</td>
<td>421.7a</td>
<td>398.6a</td>
<td>360.4a</td>
<td>371.4a</td>
<td>378.2a</td>
</tr>
<tr>
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<td>220.6a</td>
<td>402.7a</td>
<td>398.4a</td>
<td>411.7a</td>
<td>371.2a</td>
<td>242.3a</td>
<td>232.5a</td>
<td>176.8a</td>
<td>124.6a</td>
<td>118.7a</td>
<td>190.8a</td>
<td>376.8a</td>
<td>440.5a</td>
<td>400.5a</td>
<td>412.4a</td>
<td>384.1a</td>
<td>381.6a</td>
<td>363.4a</td>
</tr>
<tr>
<td>Means of cuts</td>
<td>220.9</td>
<td>379.1</td>
<td>371.6</td>
<td>370.2</td>
<td>343.7</td>
<td>238.2</td>
<td>236.8</td>
<td>184.9</td>
<td>125.2</td>
<td>121.5</td>
<td>178.8</td>
<td>364.0</td>
<td>397.8</td>
<td>373.6</td>
<td>369.1</td>
<td>332.0</td>
<td>321.9</td>
<td>316.7</td>
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</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Table 6. Effect of water treatments on plant density (plants/m²) of alfalfa cultivars

<table>
<thead>
<tr>
<th>Water treat.</th>
<th>Cuts</th>
<th>Mean</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>I₁</td>
<td>216.4a</td>
<td>394.1a</td>
</tr>
<tr>
<td>I₂</td>
<td>221.3a</td>
<td>406.1a</td>
</tr>
<tr>
<td>I₃</td>
<td>218.2a</td>
<td>389.7a</td>
</tr>
<tr>
<td>Means of cuts</td>
<td>218.63</td>
<td>393.63</td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Table 7. Effect of weeding on plant density (plants/m²) of alfalfa cultivars

<table>
<thead>
<tr>
<th>Weeding treat.</th>
<th>1</th>
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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>W₁</td>
<td>216.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>324.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>301.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>289.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>251.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>186.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>131.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>120.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>148.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>241.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>281.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>312.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>298.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>266.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>277.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>219.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>247.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W₂</td>
<td>221.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>332.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>308.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>296.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>246.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>221.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>178.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>126.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>122.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>142.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>240.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>290.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>318.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>296.4&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>213.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>240.9</td>
<td></td>
</tr>
<tr>
<td>W₃</td>
<td>212.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>320.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>311.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>287.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>271.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>250.1&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>116.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>146.0&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>280.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>309.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>284.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>262.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>220.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>216.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>236.1</td>
</tr>
<tr>
<td>Means of cuts</td>
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<td>325.9</td>
<td>313.3</td>
<td>295.3</td>
<td>279.9</td>
<td>249.5</td>
<td>217.7</td>
<td>182.2</td>
<td>127.9</td>
<td>120.0</td>
<td>145.8</td>
<td>240.0</td>
<td>284.2</td>
<td>313.6</td>
<td>293.1</td>
<td>266.2</td>
<td>226.2</td>
<td>216.6</td>
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</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Table 8. Plant height of alfalfa (cm) as affected by cultivars

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>78.4b</td>
<td>64.6b</td>
<td>70.4b</td>
<td>72.3b</td>
<td>79.4b</td>
<td>70.4b</td>
<td>66.5b</td>
<td>61.7b</td>
<td>60.7b</td>
<td>27.7b</td>
<td>60.4b</td>
<td>70.3b</td>
<td>69.7b</td>
<td>62.6b</td>
<td>74.3b</td>
<td>70.7b</td>
<td>65.4b</td>
<td>64.1b</td>
<td>68.31</td>
</tr>
<tr>
<td>C2</td>
<td>102.4a</td>
<td>108.4a</td>
<td>108.7a</td>
<td>106.4a</td>
<td>104.7a</td>
<td>101.8a</td>
<td>98.4a</td>
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<td>91.6a</td>
<td>88.4a</td>
<td>92.8a</td>
<td>108.7a</td>
<td>106.8a</td>
<td>109.1a</td>
<td>106.8a</td>
<td>101.7a</td>
<td>99.8a</td>
<td>96.4a</td>
<td>101.31</td>
</tr>
<tr>
<td>C3</td>
<td>105.7a</td>
<td>109.5a</td>
<td>106.4a</td>
<td>110.6a</td>
<td>106.3a</td>
<td>100.3a</td>
<td>99.7a</td>
<td>88.4a</td>
<td>90.8a</td>
<td>89.1a</td>
<td>94.9a</td>
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<td>105.7a</td>
<td>107.7a</td>
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<td>102.3a</td>
<td>96.4a</td>
<td>95.7a</td>
<td>101.28</td>
</tr>
<tr>
<td>Means</td>
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<td>94.20</td>
<td>95.17</td>
<td>96.8</td>
<td>90.83</td>
<td>88.20</td>
<td>80.27</td>
<td>81.03</td>
<td>78.4</td>
<td>82.70</td>
<td>95.60</td>
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<td>91.57</td>
<td>89.38</td>
<td>85.40</td>
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</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
### Table 9. Effect of water treatments on plant height (cm) of alfalfa cultivars

<table>
<thead>
<tr>
<th>Water treat.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I₁</strong></td>
<td>78.6</td>
<td>76.7</td>
<td>80.4</td>
<td>72.4</td>
<td>71.7</td>
<td>70.7</td>
<td>76.8</td>
<td>69.6</td>
<td>68.1</td>
<td>74.7</td>
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<td>68.1</td>
<td>62.2</td>
<td>72.34</td>
</tr>
<tr>
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<td>106.3</td>
<td>105.4</td>
<td>98.7</td>
<td>91.4</td>
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</tr>
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<td><strong>I₃</strong></td>
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<td>78.4</td>
<td>76.7</td>
<td>96.2</td>
<td>70.2</td>
<td>66.2</td>
<td>64.2</td>
<td>48.1</td>
<td>21.2</td>
<td>26.4</td>
<td>59.1</td>
<td>62.1</td>
<td>26.7</td>
<td>67.2</td>
<td>66.2</td>
<td>69.2</td>
<td>60.7</td>
<td>78.35</td>
<td></td>
</tr>
<tr>
<td><strong>Means of cuts</strong></td>
<td>78.83</td>
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<td>79.64</td>
<td>79.72</td>
<td>79.72</td>
<td>79.59</td>
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<td>79.59</td>
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<td>78.44</td>
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</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Weeding levels significantly affected this attribute except in the first three occasions. The treatment (W₁) caused a significant increase in plant height followed by (W₂) and (W₃), (Table 10).

### 4.2.3 Shoot/root ratio

As demonstrated in Table 11 alfalfa cultivars significantly varied in shoot/root ratio in 8 occasions throughout the experimental period. This significant variation occurred differently among the cultivars in the designated occasions.

Water treatments had a significant effect on this character six times throughout the study, where the treatment (I₂) gave significant higher shoot/root ratio followed by (I₁) and (I₃), (Table 12).

Weeding treatments also had a significant effect in shoot/root ratio 10 times during the experimental period. The treatment (W₁) recorded higher mean shoot/root ratios than (W₂) and (W₃), (Table 13).

### 4.2.4 Leaf area index (LAI)

Analysis of variance showed that there was a significant variation among alfalfa cultivars in their leaf area indices in all sampling occasions (Table 14). The cultivar (C₃) gave significantly higher LAI followed by (C₂), then (C₁).

Leaf area index was significantly affected in 12 occasions when water treatments were applied. The highest mean leaf area indices were obtained by the treatment (I₂) followed by (I₁) and (I₃), (Table 15).
### Table 10. Effect of weeding on plant height (cm) of alfalfa cultivars

<table>
<thead>
<tr>
<th>Weed-</th>
<th>1</th>
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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<th>17</th>
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</tr>
</thead>
<tbody>
<tr>
<td>ing treat.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W&lt;sub&gt;1&lt;/sub&gt;</td>
<td>104.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>110.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>101.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>99.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>96.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>94.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>88.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>78.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>76.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>81.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>89.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>98.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>98.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>96.5&lt;sup&gt;a&lt;/sup&gt;</td>
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</tr>
<tr>
<td>W&lt;sub&gt;2&lt;/sub&gt;</td>
<td>102.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>104.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>98.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>79.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>76.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>75.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>73.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>62.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>61.7&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>64.9&lt;sup&gt;a&lt;/sup&gt;</td>
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</tr>
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<td>96.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>78.1&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>78.93</td>
<td>75.93</td>
<td>66.27</td>
<td>65.67</td>
<td>66.30</td>
<td>71.73</td>
<td>78.63</td>
<td>80.37</td>
<td>79.00</td>
<td>75.10</td>
<td>71.17</td>
<td>68.50</td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Table 11. Shoot/root ratio as affected by alfalfa cultivars

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>C2</td>
<td>2.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.66&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.8&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
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<td>2.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.7&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>3.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.3&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Means of cuts</td>
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<td>2.2</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
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<td>2.8</td>
<td>2.5</td>
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<td>2.4</td>
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<tr>
<td>Lsd</td>
<td>0.78</td>
<td>0.64</td>
<td>0.69</td>
<td>0.56</td>
<td>0.76</td>
<td>0.52</td>
<td>0.52</td>
<td>0.81</td>
<td>0.67</td>
<td>0.86</td>
<td>0.69</td>
<td>0.72</td>
<td>0.62</td>
<td>0.75</td>
<td>0.82</td>
<td>0.68</td>
<td>0.74</td>
<td>0.83</td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Table 12. Effect of water treatment on shoot/root ratio of alfalfa of cultivars

<table>
<thead>
<tr>
<th>Water treat.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>I₁</td>
<td>2.7a</td>
<td>2.4a</td>
<td>2.0a</td>
<td>1.7a</td>
<td>1.6a</td>
<td>1.8a</td>
<td>2.4a</td>
<td>1.2b</td>
<td>2.4a</td>
<td>2.2a</td>
<td>1.7b</td>
<td>1.9b</td>
<td>2.2a</td>
<td>2.2a</td>
<td>2.5a</td>
<td>1.9a</td>
<td>2.2a</td>
<td>2.04</td>
<td></td>
</tr>
<tr>
<td>I₂</td>
<td>2.8a</td>
<td>2.1a</td>
<td>2.2a</td>
<td>1.8a</td>
<td>2.9a</td>
<td>2.1a</td>
<td>2.7a</td>
<td>1.9a</td>
<td>2.3a</td>
<td>2.6a</td>
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<td>2.4a</td>
<td>1.9a</td>
<td>2.3a</td>
<td>2.1a</td>
<td>2.4a</td>
<td>2.31</td>
</tr>
<tr>
<td>I₃</td>
<td>2.6a</td>
<td>2.2a</td>
<td>1.9a</td>
<td>2.1a</td>
<td>1.4a</td>
<td>2.4a</td>
<td>2.3a</td>
<td>2.2a</td>
<td>1.6a</td>
<td>2.3a</td>
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<td>2.6a</td>
<td>2.2a</td>
<td>2.5a</td>
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</tr>
<tr>
<td>Means of cuts</td>
<td>2.7</td>
<td>2.23</td>
<td>2.03</td>
<td>1.87</td>
<td>2.10</td>
<td>2.47</td>
<td>1.77</td>
<td>2.13</td>
<td>2.10</td>
<td>2.37</td>
<td>2.37</td>
<td>2.37</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Lsd</td>
<td>0.82</td>
<td>0.78</td>
<td>0.91</td>
<td>0.79</td>
<td>0.94</td>
<td>0.86</td>
<td>0.75</td>
<td>0.67</td>
<td>0.73</td>
<td>0.62</td>
<td>0.74</td>
<td>0.85</td>
<td>0.72</td>
<td>0.86</td>
<td>0.64</td>
<td>0.72</td>
<td>0.82</td>
<td>0.84</td>
<td></td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Table 13. Effect of weeding on shoot/root ratio of alfalfa cultivars

| Weed- | Cuts  |  |  |  |  |  |  |  |  |  |  |  |  |  | Mean |
| treat. | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| W1 | 2.9a | 3.1a | 2.7a | 2.8a | 3.0a | 2.9a | 2.6a | 2.4a | 2.2a | 2.1a | 2.4a | 2.6a | 2.2a | 1.9a | 2.2a | 1.9a | 2.1a | 2.46 |
| W2 | 2.7a | 2.8a | 2.5a | 2.6a | 2.1a | 2.0a | 1.9a | 1.8a | 1.2a | 1.1a | 1.4a | 1.5a | 1.4a | 1.3a | 1.7a | 1.8a | 1.6a | 1.7a | 1.84 |
| W3 | 2.4a | 2.4a | 2.3a | 2.4a | 1.8a | 1.9a | 1.1a | 1.6a | 1.1a | 0.8a | 1.1a | 1.2a | 1.2a | 1.5a | 1.6a | 1.5a | 1.6a | 1.59 |
| Means of cuts | 2.67 | 2.77 | 2.50 | 2.60 | 2.30 | 2.27 | 1.87 | 1.93 | 1.50 | 1.40 | 1.53 | 1.90 | 1.73 | 1.57 | 1.70 | 1.87 | 1.67 | 1.80 |
| Lsd | 0.86 | 0.84 | 0.79 | 0.64 | 0.72 | 0.75 | 0.66 | 0.53 | 0.61 | 0.56 | 0.73 | 0.62 | 0.75 | 0.68 | 0.54 | 0.74 | 0.76 | 0.68 |

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Table 14. Leaf area index of alfalfa as affect by cultivars

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C1</strong></td>
<td>1.81</td>
<td>1.90</td>
<td>1.92</td>
<td>1.82</td>
<td>1.73</td>
<td>1.84</td>
<td>1.56</td>
<td>1.50</td>
<td>1.46</td>
<td>1.32</td>
<td>1.36</td>
<td>1.78</td>
<td>1.68</td>
<td>1.74</td>
<td>1.66</td>
<td>1.58</td>
<td>1.46</td>
<td>1.51</td>
<td>1.65</td>
</tr>
<tr>
<td><strong>C2</strong></td>
<td>2.75</td>
<td>2.86</td>
<td>2.90</td>
<td>2.92</td>
<td>2.68</td>
<td>2.11</td>
<td>2.14</td>
<td>1.86</td>
<td>1.75</td>
<td>1.64</td>
<td>2.20</td>
<td>2.56</td>
<td>2.64</td>
<td>2.72</td>
<td>2.56</td>
<td>2.23</td>
<td>2.16</td>
<td>2.41</td>
<td></td>
</tr>
<tr>
<td><strong>C3</strong></td>
<td>2.96</td>
<td>3.04</td>
<td>2.98</td>
<td>3.22</td>
<td>2.96</td>
<td>2.88</td>
<td>2.90</td>
<td>2.76</td>
<td>2.24</td>
<td>2.12</td>
<td>2.80</td>
<td>3.11</td>
<td>2.96</td>
<td>3.04</td>
<td>2.80</td>
<td>2.96</td>
<td>2.87</td>
<td>2.85</td>
<td></td>
</tr>
<tr>
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<td>2.60</td>
<td>2.65</td>
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<td>1.77</td>
<td>1.71</td>
<td>2.26</td>
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<td>2.45</td>
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<td>2.31</td>
<td>2.22</td>
<td>2.18</td>
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<td></td>
</tr>
<tr>
<td>Lsd</td>
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<td>0.62</td>
<td>0.66</td>
<td>0.58</td>
<td>0.64</td>
<td>0.72</td>
<td>0.65</td>
<td>0.54</td>
<td>0.65</td>
<td>0.54</td>
<td>0.66</td>
<td>0.75</td>
<td>0.69</td>
<td>0.58</td>
<td>0.60</td>
<td>0.77</td>
<td>0.71</td>
<td>0.65</td>
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</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Table 15. Effect of water quality on leaf area index of alfalfa cultivars

<table>
<thead>
<tr>
<th>Water treat.</th>
<th>Cuts</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>I₁</td>
<td>2.82</td>
<td>2.98</td>
</tr>
<tr>
<td>I₂</td>
<td>2.96</td>
<td>3.14</td>
</tr>
<tr>
<td>I₃</td>
<td>2.11</td>
<td>2.96</td>
</tr>
<tr>
<td>Means of cuts</td>
<td>2.65</td>
<td>3.03</td>
</tr>
<tr>
<td>Lsd</td>
<td>0.96</td>
<td>0.78</td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Application of weeding treatments significantly affected shoot/root attribute in 12 out of 18 occasions throughout the experimental period in which the treatment (W₁) was superior to other weeding levels (Table 16).

4.2.5 Leaf to stem ratio (LSR)

Results showed that a significant variation occurred between alfalfa cultivars in their leaf to stem ratios in all sampling occasions, (Table 17). The cultivars (C₂) and (C₃) were significantly similar in almost all the occasions, but they recorded higher LSRs than the cultivar (C₁), (Table 17).

Irrigation water treatment had a significant effect on this attribute, where the highest LSRs were recorded by the treatment (I₂), followed by (I₁) and (I₃), (Table 18).

Leaf to stem ratio was significantly affected when weeding treatments were applied with a preference for the treatment (W₁) to the other levels (Table 19).

4.3 Forage production
4.3.1 Forage fresh yield

Fresh yield of alfalfa varied significantly among cultivars studied at all harvests (Table 20). The cultivars (C₃) and (C₂) were significantly similar in most of the occasions, with relative preference to (C₃), and out yielded the cultivar (C₁) considerably. The increases in fresh yield of (C₃) and (C₂) was 44.6 and 34.9% compared to the cultivar (C₁), respectively.
Table 16. Effect of weeding on leaf area index of alfalfa cultivars

<table>
<thead>
<tr>
<th>Weeding treat.</th>
<th>1</th>
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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>W₁</td>
<td>2.78a</td>
<td>2.96a</td>
<td>2.92a</td>
<td>3.12a</td>
<td>2.89a</td>
<td>2.79a</td>
<td>2.42a</td>
<td>2.36a</td>
<td>2.28a</td>
<td>2.56a</td>
<td>2.78a</td>
<td>2.78a</td>
<td>2.90a</td>
<td>2.68a</td>
<td>2.62a</td>
<td>2.71a</td>
<td>2.74</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>2.82a</td>
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<td>2.88a</td>
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<td>2.10b</td>
<td>1.94b</td>
<td>2.29a</td>
<td>2.15b</td>
<td>1.84b</td>
<td>1.96b</td>
<td>2.18b</td>
<td>2.87a</td>
<td>2.78a</td>
<td>2.69a</td>
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<td>2.52a</td>
<td>2.46a</td>
<td>2.40</td>
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</tr>
<tr>
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<td>2.89a</td>
<td>2.78a</td>
<td>2.38a</td>
<td>2.06a</td>
<td>1.86a</td>
<td>1.74a</td>
<td>1.65a</td>
<td>1.58a</td>
<td>1.72a</td>
<td>1.95a</td>
<td>2.11a</td>
<td>2.06a</td>
<td>1.96a</td>
<td>2.38a</td>
<td>2.42a</td>
<td>2.28a</td>
<td>2.13</td>
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</tr>
<tr>
<td>Means of cuts</td>
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<td>2.96</td>
<td>2.86</td>
<td>2.64</td>
<td>2.35</td>
<td>2.20</td>
<td>2.10</td>
<td>2.15</td>
<td>2.05</td>
<td>1.90</td>
<td>2.08</td>
<td>2.30</td>
<td>2.65</td>
<td>2.58</td>
<td>2.52</td>
<td>2.52</td>
<td>2.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lsd</td>
<td>0.89</td>
<td>0.92</td>
<td>0.76</td>
<td>0.52</td>
<td>0.63</td>
<td>0.68</td>
<td>0.54</td>
<td>0.62</td>
<td>0.62</td>
<td>0.53</td>
<td>0.50</td>
<td>0.54</td>
<td>0.61</td>
<td>0.57</td>
<td>0.68</td>
<td>0.64</td>
<td>0.71</td>
<td>0.72</td>
<td></td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Table 17. Leaf to stem ratio of alfalfa as affected by cultivars

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Cuts</th>
<th>Mean</th>
<th>Lsd</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>C1</td>
<td>1.54a</td>
<td>1.62b</td>
<td>1.69a</td>
</tr>
<tr>
<td>C2</td>
<td>1.83a</td>
<td>1.90a</td>
<td>1.98a</td>
</tr>
<tr>
<td>C3</td>
<td>1.94a</td>
<td>1.98a</td>
<td>2.01a</td>
</tr>
<tr>
<td>Means of cuts</td>
<td>1.77</td>
<td>1.83</td>
<td>1.89</td>
</tr>
<tr>
<td>Lsd</td>
<td>0.24</td>
<td>0.14</td>
<td>0.16</td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Table 18. Effect of water quality on leaf to stem ratio of alfalfa cultivars

<table>
<thead>
<tr>
<th>Water treat.</th>
<th>Cuts</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>I₁</td>
<td>1.86ₐ</td>
<td>1.96ₐ</td>
</tr>
<tr>
<td>I₂</td>
<td>1.9₂ₐ</td>
<td>1.₈₈ₐ</td>
</tr>
<tr>
<td>I₃</td>
<td>1.₉₀ₐ</td>
<td>1.₈₆ₐ</td>
</tr>
<tr>
<td>Means of cuts</td>
<td>1.₈₉</td>
<td>1.₉₀</td>
</tr>
<tr>
<td>Lsd</td>
<td>0.₁₆</td>
<td>0.₁₈</td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Table 19. Effect of weeding on leaf to stem ratio of alfalfa cultivars

<table>
<thead>
<tr>
<th>Weeding treat.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
<td>1.83a</td>
<td>1.92a</td>
<td>1.94a</td>
<td>1.98a</td>
<td>1.93a</td>
<td>1.90a</td>
<td>1.82a</td>
<td>1.78a</td>
<td>1.62a</td>
<td>1.71a</td>
<td>1.62a</td>
<td>1.69a</td>
<td>1.65a</td>
<td>1.72a</td>
<td>1.81a</td>
<td>1.72a</td>
<td>1.63a</td>
<td>1.79</td>
<td></td>
</tr>
<tr>
<td>W2</td>
<td>1.89a</td>
<td>1.90a</td>
<td>1.89a</td>
<td>1.62a</td>
<td>1.58b</td>
<td>1.65b</td>
<td>1.49b</td>
<td>1.52a</td>
<td>1.46b</td>
<td>1.50b</td>
<td>1.41b</td>
<td>1.44b</td>
<td>1.35b</td>
<td>1.49b</td>
<td>1.55b</td>
<td>1.51b</td>
<td>1.43b</td>
<td>1.56</td>
<td></td>
</tr>
<tr>
<td>W3</td>
<td>1.91a</td>
<td>1.86a</td>
<td>1.84a</td>
<td>1.60a</td>
<td>1.57b</td>
<td>1.51b</td>
<td>1.42a</td>
<td>1.44a</td>
<td>1.40a</td>
<td>1.43a</td>
<td>1.46a</td>
<td>1.39a</td>
<td>1.42a</td>
<td>1.50a</td>
<td>1.48a</td>
<td>1.53a</td>
<td>1.49a</td>
<td>1.54</td>
<td></td>
</tr>
<tr>
<td>Means of cuts</td>
<td>1.88</td>
<td>1.89</td>
<td>1.89</td>
<td>1.73</td>
<td>1.67</td>
<td>1.70</td>
<td>1.60</td>
<td>1.59</td>
<td>1.53</td>
<td>1.51</td>
<td>1.55</td>
<td>1.50</td>
<td>1.51</td>
<td>1.47</td>
<td>1.57</td>
<td>1.61</td>
<td>1.59</td>
<td>1.51</td>
<td></td>
</tr>
<tr>
<td>Lsd</td>
<td>0.16</td>
<td>0.18</td>
<td>0.19</td>
<td>0.15</td>
<td>0.14</td>
<td>0.16</td>
<td>0.17</td>
<td>0.18</td>
<td>0.16</td>
<td>0.14</td>
<td>0.17</td>
<td>0.15</td>
<td>0.15</td>
<td>0.18</td>
<td>0.16</td>
<td>0.17</td>
<td>0.19</td>
<td>0.12</td>
<td></td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Table 20. Fresh yield of alfalfa (t/ha) as affected by cultivars

<table>
<thead>
<tr>
<th>Culti-vars</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₁</td>
<td>8.2b</td>
<td>9.1b</td>
<td>8.7b</td>
<td>7.6b</td>
<td>8.2b</td>
<td>6.3b</td>
<td>6.0b</td>
<td>4.2b</td>
<td>3.8b</td>
<td>2.9b</td>
<td>3.2b</td>
<td>6.8b</td>
<td>7.9b</td>
<td>8.6b</td>
<td>7.2b</td>
<td>6.7b</td>
<td>5.9b</td>
<td>5.0b</td>
</tr>
<tr>
<td>C₂</td>
<td>12.9a</td>
<td>15.1a</td>
<td>15.6a</td>
<td>11.7a</td>
<td>12.2a</td>
<td>9.8a</td>
<td>7.6a</td>
<td>7.2a</td>
<td>6.9a</td>
<td>4.9a</td>
<td>6.7a</td>
<td>12.5a</td>
<td>14.7a</td>
<td>13.9a</td>
<td>11.8a</td>
<td>10.6a</td>
<td>8.3a</td>
<td>7.2a</td>
</tr>
<tr>
<td>C₃</td>
<td>14.2a</td>
<td>16.2a</td>
<td>15.6a</td>
<td>12.8a</td>
<td>13.7a</td>
<td>10.8a</td>
<td>8.5a</td>
<td>7.8a</td>
<td>6.0a</td>
<td>5.8a</td>
<td>8.9a</td>
<td>14.0a</td>
<td>16.2a</td>
<td>15.7a</td>
<td>13.6a</td>
<td>11.5a</td>
<td>9.8a</td>
<td>8.7a</td>
</tr>
<tr>
<td>LSD</td>
<td>3.21</td>
<td>2.73</td>
<td>3.14</td>
<td>2.92</td>
<td>2.49</td>
<td>2.11</td>
<td>2.06</td>
<td>2.19</td>
<td>1.96</td>
<td>1.86</td>
<td>2.24</td>
<td>2.78</td>
<td>3.08</td>
<td>3.19</td>
<td>3.01</td>
<td>2.69</td>
<td>2.19</td>
<td>1.96</td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Water treatments had a significant effect on fresh forage yield of alfalfa cultivars in 12 out of 18 sampling occasions. The treatment (I2) significantly outyielded (I1) whereas the treatment (I3) recorded a highly significant decrease in fresh forage yield in the designated time. The increase in fresh forage yield of the treatment (I2) was 22.3 and 24.3% compared to (I1) and (I3), respectively (Table 21).

Application of weeding treatments caused a significant effect in fresh forage yield in 15 out of 18 occasions. The highest mean fresh forage yields resulted when the treatment (W1) was applied whereas (W2) and (W3) showed a significant decrease in this character (Table 22). The decrease in fresh forage yield of (W2) and (W3) was 31.7 and 38.9% compared to (W1), respectively.

4.3.2 Dry yield

There was a significant variation in dry yield of studied alfalfa cultivars at all harvests (Table 23). The cultivars (C3) and (C2) were significantly similar and recorded higher dry yields than the cultivar (C1). The increase in dry yield of (C3) and (C2) was estimated by 44.9 and 39.0% compared to (C1), (Table 23).

Irrigation treatments significantly affected this character in six out of 18 harvests (Table 24). The treatment (I2) significantly recorded higher mean dry yield values, followed by (I1). However, the treatment (I3) showed a considerable decrease in this parameter. The decrease in dry yield of (I3) was 35.1 and 6.7% compared to (I2) and (I1), respectively (Table 24).
Table 21. Effect of water quality on forage fresh yield (t/ha) of alfalfa cultivars

<table>
<thead>
<tr>
<th>Water treat.</th>
<th>Cuts</th>
<th>Mean</th>
<th>LSD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>I₁</td>
<td>11.9a</td>
<td>12.3a</td>
<td>10.4a</td>
</tr>
<tr>
<td>I₂</td>
<td>12.3a</td>
<td>14.2a</td>
<td>11.6a</td>
</tr>
<tr>
<td>I₃</td>
<td>12.5a</td>
<td>13.6a</td>
<td>10.4a</td>
</tr>
<tr>
<td>Means of cuts</td>
<td>12.23</td>
<td>13.37</td>
<td>20.93</td>
</tr>
<tr>
<td>LSD</td>
<td>3.21</td>
<td>2.96</td>
<td>2.64</td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Table 22. Effect of weeding on forage fresh yield (t/ha) on alfalfa cultivars

<table>
<thead>
<tr>
<th>Weed-</th>
<th>Cuts</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
<td>10.4a</td>
<td>10.9</td>
</tr>
<tr>
<td>W2</td>
<td>12.2a</td>
<td>14.03</td>
</tr>
<tr>
<td>W3</td>
<td>10.1a</td>
<td>14.57</td>
</tr>
<tr>
<td></td>
<td>Means of cuts</td>
<td>10.9</td>
</tr>
<tr>
<td></td>
<td>LSD</td>
<td>3.24</td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Table 23. Dry yield of alfalfa (t/ha) as affected by cultivars

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Cuts</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>2.3b</td>
<td>2.5b</td>
<td>2.4a</td>
<td>2.1b</td>
<td>2.3b</td>
<td>1.7b</td>
<td>1.6b</td>
<td>1.1b</td>
<td>1.0b</td>
<td>0.8b</td>
<td>0.9b</td>
<td>1.9b</td>
<td>2.2b</td>
<td>2.4b</td>
<td>2.0b</td>
<td>1.9b</td>
<td>1.6b</td>
<td>1.4b</td>
<td>1.78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>3.6a</td>
<td>4.2a</td>
<td>4.4a</td>
<td>3.3a</td>
<td>3.4a</td>
<td>2.7a</td>
<td>2.1a</td>
<td>2.0a</td>
<td>2.0a</td>
<td>1.4a</td>
<td>1.9a</td>
<td>2.9a</td>
<td>4.1a</td>
<td>3.8a</td>
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<td>2.9a</td>
<td>2.4a</td>
<td>2.1a</td>
<td>2.92</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td>3.9a</td>
<td>4.5a</td>
<td>4.5a</td>
<td>3.1a</td>
<td>3.7a</td>
<td>3.0a</td>
<td>2.5a</td>
<td>2.2a</td>
<td>1.7a</td>
<td>1.6a</td>
<td>2.5a</td>
<td>3.9a</td>
<td>4.5a</td>
<td>4.4a</td>
<td>3.8a</td>
<td>3.2a</td>
<td>2.7a</td>
<td>2.4a</td>
<td>3.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Means of cuts</td>
<td>3.27</td>
<td>3.73</td>
<td>3.77</td>
<td>2.83</td>
<td>3.13</td>
<td>2.47</td>
<td>2.07</td>
<td>1.77</td>
<td>1.57</td>
<td>1.27</td>
<td>1.77</td>
<td>1.90</td>
<td>3.60</td>
<td>3.53</td>
<td>3.07</td>
<td>2.67</td>
<td>2.23</td>
<td>1.97</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lsd</td>
<td>1.24</td>
<td>0.82</td>
<td>1.26</td>
<td>0.86</td>
<td>0.83</td>
<td>0.69</td>
<td>0.48</td>
<td>0.51</td>
<td>0.46</td>
<td>0.48</td>
<td>0.45</td>
<td>0.61</td>
<td>0.69</td>
<td>0.86</td>
<td>0.65</td>
<td>0.49</td>
<td>0.58</td>
<td>0.66</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Table 24. Effect of water quality on forage dry yield (t/ha) of alfalfa cultivars

<table>
<thead>
<tr>
<th>Water treat.</th>
<th>Cuts</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>$I_1$</td>
<td>3.3</td>
<td>3.4a</td>
</tr>
<tr>
<td>$I_2$</td>
<td>3.4a</td>
<td>3.8b</td>
</tr>
<tr>
<td>$I_3$</td>
<td>3.4a</td>
<td>3.7b</td>
</tr>
<tr>
<td>Means of cuts</td>
<td>3.37</td>
<td>3.63</td>
</tr>
<tr>
<td>Lsd</td>
<td>0.62</td>
<td>0.46</td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Weeding treatments significantly affected dry yield of alfalfa cultivars in 15 out of 18 sampling occasions (Table 25). The highest mean dry yield was given by the treatment (W1) followed by (W2) and (W3). Decrease in dry yield as a result of (W2) and (W3) application was 36 and 34.6% compared to (W1), (Table 25).

4.4 Seed production

4.4.1 Number of racemes per plant

Analysis of variance indicated that this attribute had a significant variation among alfalfa cultivars (Table 26). The cultivars (C3) and (C2) were similar and scored higher number of racemes than (C1).

Water treatments had a significant effect on this character (Table 26). The treatment (I2) gave significantly higher number of racemes followed by (I1) and (I3). Weeding treatments did not cause any significant effect on this parameter (Table 26).

4.4.2 Number of pods per raceme

Cultivars significantly differed in this parameter. The highest mean number of pods per raceme was recorded by the cultivar (C3) followed by (C2) and (C1), (Table 27).

Irrigation water treatments resulted in a significant effect on this attribute, where the treatment (I2) gave the highest number of pods raceme. However, (I1) and (I3) were significantly similar in this character (Table 27).

Application of weeding treatments had no effect on number of pods per raceme, although the treatment (W1) showed a slight increase in this parameter (Table 27).
Table 25. Effect of weeding on forage dry yield (t/ha) on alfalfa cultivars

<table>
<thead>
<tr>
<th>Weeding treat.</th>
<th>Cuts</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>W₁</td>
<td>2.8a</td>
<td>3.3a</td>
<td>3.7a</td>
<td>2.7a</td>
<td>2.4a</td>
<td>2.5a</td>
<td>1.9a</td>
<td>1.4a</td>
<td>1.2a</td>
<td>1.3a</td>
<td>1.8a</td>
<td>2.9a</td>
<td>3.1a</td>
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<td>2.3a</td>
<td>2.1a</td>
<td>2.3a</td>
<td>1.7a</td>
<td>2.36</td>
</tr>
<tr>
<td>W₂</td>
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<td>3.6a</td>
<td>3.8a</td>
<td>2.0ab</td>
<td>1.8b</td>
<td>1.4b</td>
<td>1.1b</td>
<td>2.7b</td>
<td>0.5b</td>
<td>0.8b</td>
<td>1.2b</td>
<td>1.5b</td>
<td>1.4b</td>
<td>1.0b</td>
<td>0.8a</td>
<td>1.1a</td>
<td>0.8a</td>
<td>1.51</td>
<td></td>
</tr>
<tr>
<td>W₃</td>
<td>2.7a</td>
<td>3.7a</td>
<td>3.7a</td>
<td>1.8b</td>
<td>1.0b</td>
<td>0.8b</td>
<td>0.9b</td>
<td>0.6b</td>
<td>0.4b</td>
<td>0.7b</td>
<td>1.0b</td>
<td>1.1b</td>
<td>1.2b</td>
<td>0.9b</td>
<td>0.8a</td>
<td>1.0b</td>
<td>0.8a</td>
<td>1.33</td>
<td></td>
</tr>
<tr>
<td>Means of cuts</td>
<td>2.87</td>
<td>3.53</td>
<td>3.73</td>
<td>2.17</td>
<td>1.73</td>
<td>1.57</td>
<td>1.30</td>
<td>0.9b</td>
<td>0.7</td>
<td>0.83</td>
<td>1.20</td>
<td>1.73</td>
<td>1.93</td>
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* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.
Table 26. Effect of water quality and weeding on number of racemes per plant of alfalfa cultivars

<table>
<thead>
<tr>
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<th>W3</th>
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<th>Means</th>
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* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.

Lsd I = 0.32
Lsd C = 1.56
Lsd W = 1.38
Table 27. Effect of water quality and weeding on number of pods per raceme of alfalfa cultivars

<table>
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<th>W₃</th>
<th>Means</th>
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</thead>
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</tr>
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<tr>
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</tr>
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<td>17.5</td>
<td>15.2</td>
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<td></td>
</tr>
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<td>11.50ᵃ</td>
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</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.

Lsd I = 0.67
Lsd C = 1.14
Lsd W = 1.68
4.4.3 Number of seeds per pod

This attribute was not affected by any of the treatments applied (Table 28).

4.4.4 Thousand seed weight

There were no significant differences among cultivars in this attribute (Table 29)

Water treatments resulted in a significant effect in 1000-seed weight where the treatment (I2) was significantly superior (I1) and (I3), (Table 29).

A significant effect was noticed in this parameter where weeding treatments were applied. The treatment (W1), however, resulted in a significant increase in 1000-seed weight compared to (W2) and (W3), (Table 29).

4.4.5 Seed yield

Alfalfa cultivars significantly differed in their seed yield. The cultivars (C3) and (C2) were similar and gave significantly higher seed yields than (C1), (Table 30).

Seed yield was significantly affected when water treatments were applied. The treatment (I2) significantly exceeded (I1) and (I3), (Table 30).

Weeding treatments resulted in a significant effect on seed yield where the treatment (W1) showed a significant increase in this character compared to (W2) and (W3), (Table 30).
Table 28. Effect of water quality and weeding on number of seeds per raceme of alfalfa cultivars

<table>
<thead>
<tr>
<th>Treatments</th>
<th>W1</th>
<th>W2</th>
<th>W3</th>
<th>Means</th>
<th></th>
<th></th>
</tr>
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</tr>
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</table>

* Means followed by the same letter(s) within columns or rows are not significantly different at 0.05 level of probability according to DMRT.

Lsd I = 0.72
Lsd C = 1.05
Lsd W = 1.19
Table 29. Effect of water quality and weeding on 1000-seed weight of alfalfa cultivars

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</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.

LSD I = 0.32
LSD C = 0.52
LSD W = 0.28
Table 30. Effect of water quality and weeding on seed yield of alfalfa cultivars

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<td>-</td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.

LSD I = 1.78
LSD C = 3.72
LSD W = 2.65
4.5 Nutritive value

4.5.1 Crude protein

Cultivars were significantly different in their crude protein contents. The cultivars (C₃) and (C₂) were similar and significantly gave higher crude protein content than (C₁) (Table 31).

Neither irrigation water, nor weeding treatments had an effect on crude protein content (Table 31).

4.5.2 Crude fiber

There were no significant differences among cultivars in their crude fiber content although a slight increase in crude fiber was noticed for the cultivar (C₁), (Table 32).

Irrigation water and weeding treatments had no significant effect on crude fiber content (Table 32).

4.6 Weed measurement

Number of weeds/unit area:

Cultivars were not significantly different in this measurement (Table 33). Water treatments showed a highly significant difference in number of weeds, where the treatment (I₃) scored the highest number of weeds to the other treatments (Table 33).

Weeding treatments resulted in a significant variation in number of weeds. The treatment (W₃) showed a significant increase in this character followed by (W₂) whereas (W₁) recorded the lowest number of weeds (Table 33).
Table 31. Effect of water quality and weeding on crude protein content of alfalfa cultivars

<table>
<thead>
<tr>
<th>Treatments</th>
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<th>Means</th>
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</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.

Lsd I = 4.12
Lsd C = 5.47
Lsd W = 4.18
Table 32. Effect of water quality and weeding on crude fiber content of alfalfa cultivars

<table>
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<tr>
<th>Treatments</th>
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<th>W2</th>
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<th>Means</th>
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<td>20.5</td>
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<td>20.63a</td>
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<td>21.84a</td>
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</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.

Lsd I = 2.84
Lsd C = 3.36
Lsd W = 3.15
Table 33. Effect of water quality and weeding on number of weeds per unit area (used plants/feddan) of alfalfa cultivars

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<thead>
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<th>Treatments</th>
<th>$W_1$</th>
<th>$W_2$</th>
<th>$W_3$</th>
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<td>C$_3$</td>
<td>2118.4</td>
<td>2517.6</td>
<td>2920.7</td>
<td>C$_3$</td>
</tr>
<tr>
<td><strong>Means</strong></td>
<td>2308.1$^c$</td>
<td>2511.2$^b$</td>
<td>2594.0$^a$</td>
<td>-</td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) within columns of rows are not significantly different at 0.05 level of probability according to DMRT.

Lsd I  =  49.38
Lsd C  =  38.19
Lsd W  =  58.27
CHAPTER FIVE
DISCUSSION

5.1 Nodulation

In this study for alfalfa cultivars, irrigation water and weeding treatments had no effect on number of nodules per plant. On the other hand, cultivars under study significantly differed in number of effective nodules, nodule fresh and dry weights, whereas water and weeding treatments had no effect. The two introduced cultivars Cuf101 and Siriver were significantly superior to the local one Hegazi in these nodulation attributes. This result is in agreement with Abu Suwar and Mohamed (1997) who found that, the introduced cultivar Pioneer 5929 was superior to the local Hegazi in nodulation. Smith et al. (1999) also pointed out that alfalfa cultivars differed in their nodulation. This is expected since both varieties (Cuf101 and Siriver) are improved varieties compared to the local Hegazi.

5.2 Vegetative growth

Cultivars studies were significantly different in their plant densities in most of the occasions (3rd – 11th cuts). The introduced cultivars gave higher plant densities than the local one. This may be attributed to the nodulation attributes. The effect on plant density was more pronounced in the first and middle cuts due to the fact that the number and effectiveness of rhizobium decrease with the age of alfalfa. Similar results were reported by Abu Suwar and Mohamed (1997) and
El Sheikh et al. (2006) who pointed out that nodulation improved plant density of alfalfa.

Alfalfa cultivars had a significant variation in their plant height, leaf area index, shoot/root ratio and leaf to stem ratio in most of the sampling occasions. The introduced cultivars exceeded the local one in these characters. This may be due to the increase in nodulation attributes mentioned above. These differences may also be attributed to the differences in morphological features and development between alfalfa cultivars. Tiejun et al. (2008) reported that, alfalfa cultivars are different in their morphology and development. The same results were reached by Jung and Lamb (2006).

Irrigation water treatments had a significant effect on plant density, plant height, leaf area index, shoot/root ratio and leaf to stem ratio. This effect was at concurrent with damira months where the river water brings weed seeds and other substances, which may be toxic to alfalfa (alleophathy) as reported by Ming and Miller (1995). This reason may therefore, be a cause in plant density reduction.

Weeding treatments had no significant effect on plant density of alfalfa cultivars. Beck et al. (1999) reported that, weeds in established stands of alfalfa decreased yield and crop quality but did not affect the plant density.

5.3 Forage yield

The studied alfalfa cultivars were significantly different in their forage fresh and dry yields in all cuts. The introduced cultivars had
a significant increase in forage fresh and dry yields compared to the local one. Significant yield increment of introduced cultivars may be attributed to the increase they scored in the growth parameters; plant density, plant height, leaf area index and leaf to stem ratio and nodulation, which all contribute final yield. Khair (1992) reported that the yield of Hegazi and Pioneer cultivar was not significantly different. On the other hand, Ali et al. (1998); Mohamed (2000) and Fadul (2001) found that, the local cultivar Hegazi was superior to the introduced Pioneer in fresh and dry yields.

Application of water treatments resulted in a significant effect on fresh and dry yields of alfalfa cultivars. The river screened water treatment gave significantly higher yields than the bore hole water treatment, whereas the river water without screening caused a significant decrease in yield. Reduction in yield, as a result of bore hole water application may be attributed to the fact that alfalfa yield is reduced in saline conditions as mentioned by Abu Suwar (2004). On the other hand, a significant decline in yield was noticed when river water without screening was applied. This reduction was more pronounced during autumn months and last summer where damira water brought considerable amount of weed seeds, which severely infested the crop.

Weeding treatments significantly affected fresh and dry yields of alfalfa cultivars. Monthly weeding treatment scored significantly higher yield than weeding every two and three months. Reduction in yield due to application of the latter two treatments may be attributed to the fact
that alfalfa has a poor competitive ability with weeds (Lukh and Nal) present in the field, which may have threaten crop persistence. Similar results were reported by many authors (Hall et al., 1995; Beck et al., 1999; Chapko et al., 1991; Doll, 2000 and Abu Suwar, 2004).

5.4 Seed production

In this study, the introduced cultivars gave significantly higher number of racemes per plant and number of pods per raceme than the local cultivar. Differences did not occur among cultivars in number of seeds per pod and 1000-seed weight. The introduced cultivars were, therefore, superior to the local one in total seed yield as a result of significant increase in the attributes mentioned above.

Mohamed (2000) found that, the local cultivar Hegazi and the introduced Pioneer did not significantly differ in their total seed yield. Smith et al. (1999) and Mumpries and Hughes (2006) stated that, alfalfa cultivars differ in their seed production.

Application of irrigation water treatments had no significant effect on seed production attributes, with relative preference in favour of river screened water treatment. However, weeding treatments significantly affected 1000-seed weight, which is reflected in an increase in seed yield caused by monthly weeding treatment. Michael et al. (2002) reported that, weeds affect seed production of alfalfa.
5.5 Nutritive value

The cultivars under study were significantly different in their crude protein and crude fiber contents. The introduced cultivars recorded higher crude protein and lower crude fiber contents compared to the local cultivar. Many authors stated that alfalfa cultivars differ in their quality (Kalu and Fick, 1983; Sanderson and Wedin, 1988; McQueen and Belanger, 1994; Maruin et al., 2000 and Humpries and Hughes, 2006).

5.6 Weed measurements

Cultivars were not significantly different in number of weeds per unit area. Water treatments, on the other hand, showed a highly significant difference in this measurement where the river water without screening treatment scored the highest estimates during damira months. This is probably caused by weeds grown as a result of weed seeds brought by river water. The weeds grown during and after this period, and was not available before, included: *Ambrosia martima* and *Eclipta alba* (family: Asteraceae), some *Cyperus* species, *Dicanthium annulatum*, *Cymbopogon nervatus* and *Phragmites ustratus* (family: Poaceae), *Polygonum glabrum* (family: Polygonacea), *Tamarix nilotica* (family: Tamaricaceae) and *Amaranthus spinosus* (family: Amaranthaceae).

Weeding every two and three months recorded higher number of weeds compared to monthly weeding and this was expected according to weeding intervals.
SUMMARY AND RECOMMENDATIONS

A field experiment was conducted in the Demonstration Farm of the Faculty of Agriculture at Shambat to study the effect of water quality on growth, yield and seed production of three alfalfa cultivars. Three levels of each water quality and weeding were used in the experiment. The parameters taken included: number of nodules, nodule fresh and dry weights, plant density, plant height, shoot/root ratio, leaf area index, leaf to stem ratio, forage fresh and dry yields, number of racemes per plant, number of pods per raceme, number of seeds per pod, 1000-seed weight, total seed yield, crude protein and crude fiber content and number of weeds per unit area.

The results of this study can be summarized as follows:

1- Alfalfa cultivars significantly varied in nodule fresh and dry weights, number of effective nodules, plant density, plant height, shoot/root ratio, leaf area index, leaf to stem ratio, fresh and dry yields, number of racemes per plant, number of pods per raceme, total seed yield and crude protein and crude fiber contents. This study showed that the introduced cultivars favoured the growth, yield, seed production and quality of the crop.

2- Water treatments had a significant effect on plant density, plant height, shoot/root ratio, leaf area index, leaf to stem ratio, fresh and dry yields, number of racemes per plant, number of pods per racemes, 1000-seed weight, total seed yield and number of weeds per unit area.
3- Weeding levels caused a significant effect on plant height, shoot/root ratio, leaf area index, leaf to stem ratio, fresh and dry yields, 1000-seed weight, seed yield and number of weeds per unit area. Monthly weeding significantly enhanced vegetative growth and crop yield. The yield of alfalfa cultivars declined considerably during damira season.

Therefore, this study indicated the importance of finding out an applicable method of irrigation during damira months to minimize the dramatic decline in yield to a reasonable range.
REFERENCES


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Mustafa, F.A. (1996). Effects of sowing methods and phosphorus application on the performance of two alfalfa (*Medicago sativa*


APPENDIX 1

Maximum and minimum temperatures (°C), relative humidity (%) and rainfall (mm) at Shambat during the experimental period

<table>
<thead>
<tr>
<th>Month</th>
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<th>Minimum temperature</th>
<th>Relative humidity</th>
<th>Rainfall</th>
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<td></td>
</tr>
<tr>
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<td>19</td>
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</tr>
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<td>December</td>
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<td>20.0</td>
<td>47</td>
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</tr>
<tr>
<td>2006</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>January</td>
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Source: Shambat Agrometeorological Observatory.