*Asian Journal of Chemistry* Vol. 17, No. 3 (2005), 1995–2000

# Relationships between Color and Some Properties in Red-Reddish and Neighbour Soils in Isparta, Turkey

MESUT AKGÜL*, A. ALI IŞILDAR and LEVENT BAŞAYİĞİT
*Department of Soil Science, Faculty of Agriculture*
*University of Süleyman Demirel, Isparta, Turkey*
*E-mail: makgul@ziraat.sdu.edu.tr*

Relationships between soil colour and some selected properties of eighty soil samples were investigated. The samples were collected from surface and subsurface horizons and/or layers of red-reddish coloured soils and neighbour soils located in Isparta, Turkey. Soil samples were analyzed for lime, organic matter, free iron oxide, soil reaction, cation exchange capacity, and particle size distribution. In addition, colour parameters (hue, value and chroma) and redness rating of soil samples were also determined. The dominant hues on more stable older geomorphic surfaces and more oxidized drainage conditions are 2.5 and 5 YR. While 7.5 YR is dominant on surfaces related to erosion and transportation, 10 YR generally is observed on examination of all landscape positions and all drainage conditions. It was found that there were significant differences for redness rating, free iron oxide and lime contents of soils that have different hue. Meaningful differences were not obtained for cation exchange capacity, organic matter, clay, silt and sand contents of soils. In addition to these results, the significant correlation coefficients were obtained to be 0.76 between redness rating and free iron oxide, to be 0.68 between hue and free iron oxide, to be 0.68 between lime and dry value.

**Key Words: Free iron oxide, Soil colour, Red soil.**

## INTRODUCTION

Soil colour is the most obvious and easily determined soil characteristic. Although, it has little known direct influence on the functioning of the soil, colour is one of the most easily determined soil properties and other more important soil characteristics can be inferred from soil colour. Therefore, soil colour is one of the most useful attributes to characterize and differentiate soils. It occurs as a result of pedogenic processes. It also affected by the physical, chemical and mineralogical properties of soils. Sensing and determining of soil colour easily has increased utility in soil studies. Some broad generalizations are also possible. Black soil usually indicates the presence of organic matter. Red colour indicates the presence of hematite in the free iron oxide (FIO) common in well-oxidized soils[1].

There are two more common ways to determine soil color: (i) the most convenient is measuring in the field by comparison with a colour chart[2],

(ii) measured in the laboratory by using diffuse reflectance spectrophotometer. Empirical colour indices that combine the three parameters are also useful[3]. One of them is redness rating (RR), modified by Torrent *et al.*[4], which has been used to obtain semi-quantitative measurements of hematite in soils.

Soil colour *per se* has little significance. The importance of soil colour relates to the fact that soil properties like organic matter, iron mineralogy and moisture content of soils are strongly related to soil colour, all of which are used to classify and make interpretations about soils[5]. Iron oxides are useful field indicators of pedogenic environments for three reasons: (i) they include several minerals, (ii) these minerals have different colours, and (iii) the type of mineral formed is influenced by the environment. Therefore, recognizing the iron oxide mineral in the field by its colour has a potential to yield information about pedogenesis[6].

## EXPERIMENTAL

The study area is located in the passage zone between the coastal belt and the continental climate of Central Anatolia and has plateau type of Mediterranean climate. Annual precipitation varies between 600 and 750 mm and annual mean temperature is 10–12°C in this area[7]. Soil temperature regime is mesic and soil moisture regime is xeric-ustic[8, 9]. Soil parent materials were weathering yields of limestone in most of the study area. Soils sampled have generally formed on Holocene and late Pleistocene deposits[10].

In this study, eighty surface and subsurface soil samples taken from red-reddish coloured soils and adjacent soils that have similar pedogenic factors (physiography, parent material, climate and vegetation) in Atabey, Aksu, Eğirdir, Şarkikaraağaç and Yenisarbademli districts of Isparta province were used. The study area soils had been under cultivation for a long term.

The moist and dry soil colours were described by using Munsell soil colour charts[2] *in-situ*. In soil samples, free iron oxide by sodium citrate-bicarbonate-dithionit method, organic matter (OM) by modified Walkley-Black method[11], pH in 1 : 1 soil-water suspension, cation exchange capacity (CEC) by ammonium acetate method, calcium carbonate equivalent by volumetric method using Scheibler calcimeter and particle size distributions by Bouyoucos hydrometer method[12] were determined and redness ratings (RR) were calculated by the relationship

$$RR = [(10 - H)C]/V$$

where V and C are the numerical values of Munsell value and chroma, respectively and H is the figure preceeding YR in the Munsell hue so that H value is 10 for 10 YR and 0 for 10 R[4]. One way ANOVA and simple correlation tests were used for the examination of relationships between measured soil properties and soil color[13].

## RESULTS AND DISCUSSION

**The soil colour and topography relations:** The distributions of soils having separate hue on four landscape positions are summarized in Fig. 1. Hues of soils were determined to be 2.5, 5, 7.5 and 10 YR. Data indicate that there is a clear relation between soil hue and topography. While the 10 YR hue was observed in similar percentages on all landscape positions, the 2.5 and 5 YR hues were not found on poor drained-toe slope positions. Red and reddish colours were usually described on stable well-drained surfaces. Most of the soils having 2.5 YR hue were determined on foot-slope position (56%) and on summit position (38%). Similarly, the percentages on foot-slope and summit positions for soils having 5 YR hue were 48 and 40%, respectively. This case could be attributed to higher FIO contents, depending on advanced weathering and aerobic conditions; depending on rapid drainage on foot-slope and summit positions. Hematite minerals that occur under aerobic conditions create red colour in soils[6]. Hematite usually coexists with goetite and the redness of a hematite containing soil increases with its hematite contents[14]. Therefore, red colour indicates the presence of hematite in the FIO common in well-oxidized soils[1].

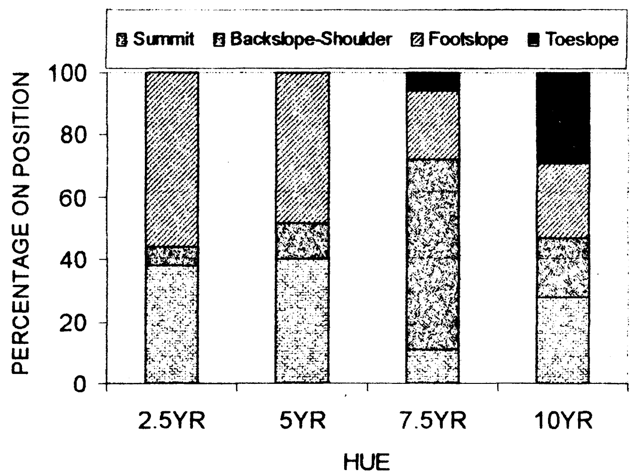


Fig. 1. The distributions of soils have separate hue on four landscape positions

Although the soils on more stable and older geomorphic surface have usually 2.5 and 5 YR hues, the soils on erosional slopes have usually 7.5 YR hue. The percentage of soils that have 7.5 YR hue on back slope and shoulder positions is the highest, 61%. The reason of this could be associated with the presence of lower iron oxides and higher lime contents, and to be younger of soils due to erosion on these positions, because light colours like white-yellow of lime mask the red color of iron minerals and cause usually brownish colours.

**The relationships between soil colour and selected soil properties:** Means and standard deviations obtained from one way ANOVA analysis results that indicate the relationships between soil colour and selected soil properties by using soil hue groups (2.5, 5, 7.5 and 10 YR) are given in Fig. 2. In addition, the results relating to correlation coefficients determined between colour parameters and other soil properties are summarized in Table-1.

These results indicate that the hue was not affected by difference in soil moisture, but the values show a decrease of 0.5–2 munsell units from a dry to a moist state. Chroma shows only a decrease of 0.5–1 munsell unit in some soils. There were similar correlations between colour parameters and other soil properties in both dry and moist stage.

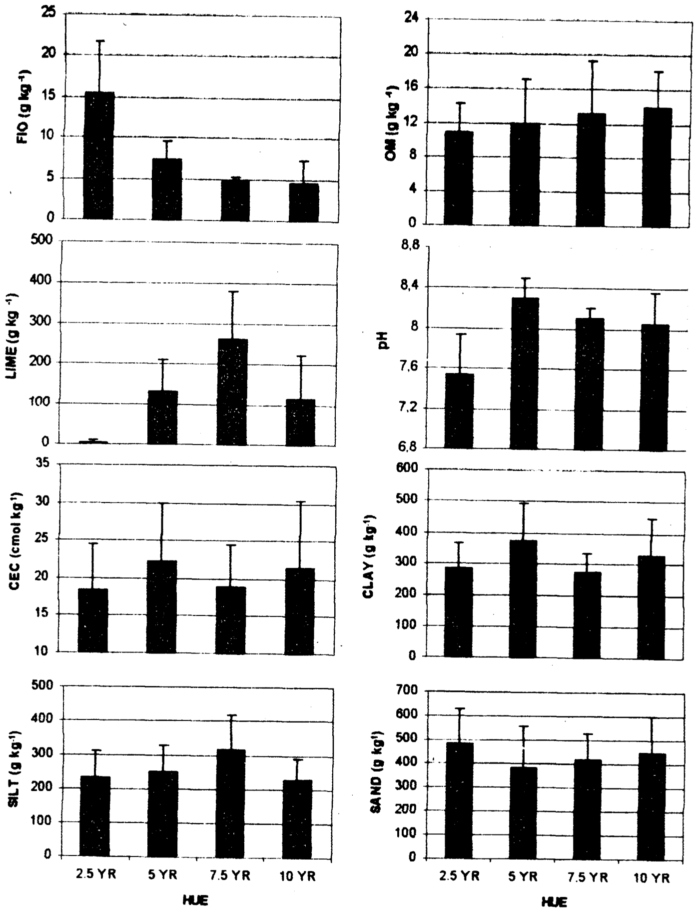


Fig. 2. The means and standard deviations of free iron oxide (FIO), organic matter (OM), lime, pH, cation exchange capacity (CEC), clay, silt and sand values for different hues

TABLE-1
CORRELATIONS AMONG COLOUR PARAMETERS AND SOME SOIL PROPERTIES

| Color components | Soil properties | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | FIO† | OM | Lime | CEC | pH | Clay | Silt | Sand |
| Hue‡ | –0.68** | 0.23* | 0.35** | 0.07 | 0.31** | –0.02 | 0.06 | –0.02 |
| Value-dry | –0.54** | –0.01 | 0.68** | –0.08 | 0.47** | –0.07 | 0.29* | –0.15 |
| Chroma-dry | 0.58** | –0.20 | –0.45** | –0.22* | –0.42** | –0.23* | –0.25* | 0.30* |
| Value-moist | –0.26* | –0.05 | 0.60** | –0.09 | 0.25* | –0.14 | 0.42** | –0.13 |
| Chroma-moist | 0.62** | –0.30 | –0.20 | –0.25* | –0.52** | –0.19 | –0.02 | 0.15 |
| RR | 0.76** | –0.24* | –0.51** | –0.14 | –0.53** | –0.09 | –0.19 | 0.16 |

†FIO = free iron oxide, OM = organic matter, CEC = cation exchange capacity, RR = redness ratio.

‡Ranked as 2.5 YR = 1, 5 YR = 2, 7.5 YR = 3 and 10 YR = 4.

Redness rating values varied between 0 and 15 and showed significant differences for different hue groups. Means and standard deviations of RR values for 5, 7.5 and 10 YR were $4.25 \pm 1.44$, $1.65 \pm 0.36$ and $0.0 \pm 0.0$, respectively. The highest RR value was found to be $11.04 \pm 0.48$ for 2.5 YR hue. The highest FIO content was also determined in 2.5 YR hue. The mean FIO contents for hue groups were 15.53, 7.33, 4.66 and 4.55 g $kg^{-1}$, respectively. The minimum and maximum values of FIO contents for hue groups of 2.5, 5, 7.5 and 10 YR were determined to be 8.3–23.3, 4.4–14.6, 3.3–5.9 and 2.8–15.7 g $kg^{-1}$, respectively. The mean values of FIO were significantly different ($p \leq 0.01$) for 2.5, 5 and 7.5 YR hue groups, but not different at $p \leq 0.05$ level for 7.5 and 10 YR hue groups. In addition, the significant negative correlation ($r = -0.68$, $p < 0.01$) was determined between hue and FIO content. There also was a significant correlation relationship ($r = 0.76$, $p < 0.01$) between redness rating and FIO contents. On the other hand, the soil that showed a colour of 10 YR 6/6 has not red and reddish colours in spite of high FIO content (15.7 g $kg^{-1}$). The reason of this case could be associated with to be the lepidocrocite form of FIO. This soil has clay texture and hydrological conditions that cause it to be wet for a longer time within a year. It was also observed that lime content is lower than 3.0 g $kg^{-1}$. Lepidocrocites occur in the non-calcareous soils under aerobic and anaerobic conditions. If lepidocrocite concentrations are to be lower than 20 g $kg^{-1}$, the hue may be 10 YR[6].

The results showed that there are more significant relationships between FIO and all color parameters except moist value (Table-1). While FIO increased, lower hue and value were determined. The relationships determined between dry values and FIO were more significant according to moist values.

Organic matter content increased from 2.5 to 10 YR hue (Fig. 2). Contrary to expectation, the significant relationship was not found between especially value and OM content. It was only found that there are significant relationships ($p \leq 0.05$) between OM and both hue and RR (Table-1). We think that this result could be attributed to the wideness of the studied geographic region that has very different landscape positions and soil texture. Schulze *et al.*[15] studied the colour-organic matter relationships to test the hypothesis that Munsell value and OM content are more closely related for soils occurring together in the soil landscapes than for soils over a wide geographic region. They have also found that the relationship between Munsell value and organic matter content was not predictable if soil texture varied widely within the landscape.

Lime contents were found to be 4.6, 131.4, 262.2 and 115.9 g $kg^{-1}$ for 2.5, 5, 7.5 and 10 YR hue groups, respectively (Fig. 2). Lime content increased from 2.5 to 7.5 YR hue. Although mean lime content for 10 YR hue was lower than that for 7.5 YR hue, this value was very high. Also, there are meaningful relationships between lime and all colour components except moist chroma (Table-1). Similar relationships were obtained for pH too. While 5, 7.5 and 10 YR hue groups showed similar pH values, pH for 2.5 YR hue was found lower. This case could be attributed to advanced weathering and leaching processes in soils, which have 2.5 YR hue. This recognition was confirmed with high FIO and low calcium carbonate contents in soils, which have 2.5 YR hue.

The meaningful differences for hue groups were not obtained among means of CEC, clay, silt and sand contents (Table-1). But, there was a significant relationship between silt fraction and moist value.

## Conclusion

Topography and drainage conditions affect the hue of soil. Red colour dominated in the two locations: (i) soils have low lime content, (ii) older and more stable geomorphic surfaces. Dominant hue was 7.5 YR on lime-rich and deformed surfaces. Hue was affected by lime and especially FIO contents and type of iron minerals. There are also meaningful relationships between FIO, lime, pH values and colour components. The 10 YR hue was observed in different topographical features and drainage conditions. Consequently, soil colour occurs as a result of soil forming conditions and is affected by some physical and chemical soil properties.

## REFERENCES

1. S.W. Buol, F.D. Hole, R.J. McCracken and R.J. Southard, Soil Genesis and Classification, 4th Edn., Iowa State University Press, Ames, Iowa 50014 (1997).
2. Munsell Color Company, Munsell soil color charts, in: Gretag Macbeth (Ed.), 2000 Revised Washables, 617 Little Britain Road, New Windsor, NY 12553 (2000).
3. J. Torrent and V. Barron, in: J.M. Bigham and E.J. Ciolkosz (Eds.), Laboratory Measurement of Soil Color: Theory and Practice, SSSA Special Publication Number 31, SSSA, Inc., Madison, Wisconsin, USA. pp. 21–33 (1993).
4. J. Torrent, U. Schwertman and D.G. Schulze, *Geoderma*, **23**, 191 (1980).
5. F.P. Donald, R.B. Bryant, A.K. Batchily, A.R. Huete, S.J. Levine, M.D. Mays and R. Escadafal, in: J.M. Bigham and E.J. Ciolkosz (Eds.), Correlations between Field and Laboratory Measurements of Soil Color, SSSA Special Publication Number 31, SSSA, Inc., Madison, Wisconsin, USA, pp. 35–49 (1993).
6. U. Schwertmann, in: J.M. Bigham and E.J. Ciolkosz (Eds.), Relations between Iron Oxides, Soil Color, and Soil Formation, SSSA Special Publication Number 31, SSSA, Inc., Madison, Wisconsin, USA, pp. 51–69 (1993).
7. M. Utku, Isparta İklim Etüdü, DMİGM, Ankara (1990).
8. M. Akgul, L. Başayiğit, Y. Uçar and M. Müjdeci, Atabey Ovasi Topraklari, SDU, Zir. Fak. Arş, Raporlari Serisi: 1, Isparta, Turkey (2001).
9. U. Dinc, S. Senol, S. Kapur, I. Atalay and C. Cangir, Türkiye Topraklari, Ç.Ü. Ziraat Fakültesi Genel Yayin No. 51, Adana, Turkey (1993).
10. MTA, 1/250000 Ölçekli Isparta jeoloji haritasi, MTA Ens, Ankara (1997).
11. Soil Survey Division Staff, Soil Survey Manual, USDA Handbook No. 18, US. Government Printing Office, Washington, DC 20402 (1993).
12. Soil Survey Laboratory Staff, Soil Survey Laboratory Methods Manual, Soil Survey Investigation Reports No. 42, NSSC, NRCS, USDA (1996).
13. O. Duzgunes, T. Kesici and F. Gurbuz, İstatistik Metodlari, Ankara Universitesi Ziraat Fakültesi yayinlari No 1291 (1993).
14. C.W. Childs, B.A. Goodman and G.J. Churchman, in: M.M. Mortland and V.C. Farmer (Eds.), Application of Mössbauer spectroscopy to the study of iron oxides in some red and yellow/brown soil samples from New Zealand, Proc. Int. Clay Conf., Oxford, 1978, Elsevier Science Publication, Amsterdam, Netherlands, pp. 555–565 (1979).
15. D.G. Schulze, J.L. Nagel, G.E. Van Scoyoc, T.L. Henderson, M.F. Baumgardner and D.E. Stott, in: J.M. Bigham and E.J. Ciolkosz (Eds.), Significance of Organic Matter in Determining Soil Colors, SSSA Special Publication Number 31, SSSA, Inc., Madison, Wisconsin, USA, pp. 71–90 (1993).

(*Received*: 24 December 2004; *Accepted:* 7 May 2005) AJC-4198